OIL·SHALE·TRACT·C-b

ENVIRONMENTAL BASELINE PROGRAM

NOVEMBER '74- OCTOBER '76

FINAL REPORT

REGIONAL AND TEMPORAL SETTING

VOLUME 1

C-b SHALE OIL VENTURE • ASHLAND OIL, INC.
OCCIDENTAL OIL SHALE, INC., OPERATOR

U. S. DEPARTMENT OF THE INTERIOR

PROTOTYPE OIL SHALE LEASING PROGRAM

OIL SHALE TRACT C-b

ENVIRONMENTAL BASELINE PROGRAM

FINAL REPORT

(November 1974 Through October 1976)

VOLUME I

REGIONAL AND TEMPORAL SETTING

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ACKNOWLEDGMENTS

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The Environmental Baseline Program on Tract C-b was undertaken to fulfill the requirements of the Federal Oil Shale Prototype Lease granted by the U. S. Department of the Interior. Methodologies selected for obtaining the data for the various disciplines are standard, accepted practices for the particular discipline. Once initiated, the individual programs were expanded in order to 1) obtain descriptive data on which to base future development monitoring programs, and 2) to fulfill the Lessee's interest in operating within parameters protective of the natural environment.

Mapping the stratigraphic units and ascertaining their structural configuration were some of the objectives of the geologic program. Abundant fracturing and some minor faulting were found in the sandstones and siltstones of the Tertiary Uinta Formation which mantles the surface of the Tract. The fractures and faults, while striking in the same direction as major features found outside the study area, are not considered significant geologically as they do not extend downward into the underlying Parachute Creek member of the Green River Formation. Fracturing and faulting are important from a pedological point of view in that fractures in parent material provide a different environment for soil development and subsequent development of vegetation.

Dendrochronology studies suggest that over the past 500 years the climate of the Piceance Basin has been similar to the present. Precipitation ranges from 12 to 24 inches per year. Most of the precipitation is received in the winter as snow with occasional monthly amounts up to 3 inches occurring in the summer when convectional thundershowers bring scattered rains to the area. Frontal activity in winter brings snow and the spring melt causes high surface runoff as well as recharge of the ground water system for the Basin.

In the semi-arid regions of northwest Colorado evaporation and transpiration losses are high. These high evapotranspiration losses combined with low precipitation make those water courses exhibiting perennial flows reliant on ground water discharge for their baseflow. Dramatic changes in the baseflow along Piceance Creek are evident from stream flow records spanning the 1972 and 1973 water years. Records from surface water gauging stations show the yearly flow for the 1973 water year and subsequent water years is approximately twice the yearly mean for 1972 and prior water years. Such an increase in

baseflow might be attributed to effects of the underground nuclear gas stimulation test known as Project Rio Blanco.

Poor quality water discharged from springs in some parts of the Piceance Basin causes an increase in total dissolved solids as Piceance Creek and Yellow Creek approach the White River. The water quality in springs on the upper reaches--in the area of the Federal Oil Shale Lease Tract C-b--approximates that of ground water in the shallow "upper" aquifer and the alluvial aquifer. The quality of water in these two aquifers and in the streams, although moderate in dissolved solids, is suitable for agricultural use.

Seven soil series occur on Tract C-b and the surrounding study area. The most predominant soil is the Rentsac series. This soil formed in residium on broad uplands from fractured sandstone parent materials. The Redcreek series, which is closely associated with the Rentsac, formed on ridgetops and narrow uplands over massive sandstones. The shallower Redcreek and the Rentsac together make up a major soil complex. Both soils are associated with pinyon-juniper and Douglas-fir forests. The Redcreek series also underlies bunchgrass communities. Other upland soils include the Forelle and Piceance series. Upland sagebrush communities are strongly associated with these soils.

The rolling topography of the Tract, dissected by north-south drainages, is dominated from a vegetal standpoint by the pinyon-juniper woodland. Three other habitat types have been designated as major for the C-b Tract study area: chained pinyon-juniper rangeland, upland sagebrush, and bottomland sagebrush. These major habitat types have grown on four major soil series which developed principally over three stratigraphic units.

The native vegetation of the upland has been much modified by chaining programs initiated in the 1960's. Both pinyon-juniper woodlands and chained, pinyon-juniper areas contain a diverse population of small mammals, avifauna, and arthropods. The larger mammals of the Tract--particularly the mule deer--congregate in the grassy and shrubby meadowlands and in alluvial areas that serve as lateral approaches to the woodland covered uplands. These areas provide food and shelter during the winter.

The faunal character of the Tract area and the use of the Tract by wildlife change with the seasons. Neither of these presently conflict with man's actions.

As part of the baseline program a survey of the aesthetic environment and archaeological studies were undertaken. Both of these disciplines, cultural in nature, have a basis in the physi-

cal sciences and one finds many interactions between these disciplines and the physical environment.

The method of surveying the scenic resources of the Piceance Creek basin relies on a regionalization based on physiographic features. Because of the monotony exhibited by the basin in the vicinity of the Tract only the vertical cliffs in Scandard Gulch convey a sense of visual change. The cliffs are found in lateral draws where deer seek shelter from winter snows. The cliffs themselves provide nesting grounds for several avian species and for several small mammal species. In addition, they form the local outcropping for the Scandard Gulch sandstone which was used in mapping the surface geology of the Tract.

From a cultural standpoint artifacts have been found by archaeological investigators that suggest man had used the Piceance Basin for hunting and gathering roughly 7000 years ago. The Basin was never more than lightly occupied and herding became an agricultural effort in the last part of the 19th century and has continued to the present time.

Pre-industrial man faced many short-term constraints based upon the physical environment. Thus an appreciation of topography, geology, and climate, to mention a few, are necessary in understanding the history of early man. In the 20th century, man while not so reliant on or constrained by the physical conditions, still finds that decisions for development are based on prior historical occurrences. The effects of man on the environment and the environment on man are found to be active, however subtly, from generation to generation. The generation of the baseline data will aid in understanding the natural environment and the multitudinous interactions that exist therein; planning based on this study will aid in eliminating or minimizing deleterious impacts of future development.

1 INTRODUCTION

The Oil Shale Tract C-b is located in northwestern Colorado in Rio Blanco County. It consists of approximately 5280 acres of federally owned land described as follows:

Township 3 South, Range 96 West, 6th Principal Meridian
Sec. 5: W½ SE¼, SW¼;
Sec. 6: Lots 6 and 7, E½ SW¼, SE¼;
Sec. 7: Lots 1, 2, 3, 4, E½ W½, E½ (All);
Sec. 8: W½ NE¼, NW¼, S½;
Sec. 9: SW¼;
Sec. 16: NW¼, W½ SW¼;
Sec. 17: All;
Sec. 18: Lots 1, 2, 3, 4, E½ W½, E½ (All).

Township 3 South, Range 97 West, 6th Principal Meridian
Sec. 1: S½;
Sec. 2: SE¼;
Sec. 11: E½;
Sec. 12: All;
Sec. 13: N½;
Sec. 14: N½ NE¼.

Tract C-b is governed by the terms and conditions of The Federal Oil Shale Prototype Lease Program as administered by the Area Oil Shale Supervisor's Office (AOSSO); U.S. Department of the Interior, Geological Survey; Grand Junction, Colorado, under the supervision of Mr. Peter Rutledge. Lease stipulations specifically require the collection of environmental baseline data for a period of at least two consecutive full years. The Lease also requires the collection and analyses of environmental baseline data in the following areas: surface water, ground water, air quality, flora and fauna, soil survey and productivity assessment, and archaeology. The data generated in these and other disciplines during the baseline period have been fully disclosed and reported in nine quarterly data reports, eight summary reports, and the first Annual Summary and Trends Report, which contains an analysis of the first year's data collection effort. These reports have been submitted to the Area Oil Shale Supervisor's office; they are available in that office for public review and inspection.

This Final Environmental Baseline Report for Oil Shale Tract C-b covers a two-year environmental data collection program. This program was initiated in part to satisfy the requirements of the Environmental Stipulations attached to the Oil Shale Lease granted by the United States Department of the Interior, and in part by the Lessee's desire to operate within parameters protective of the natural environment. This Report consists of five volumes and the Executive Summary. These volumes are: Volume 1, Regional and Temporal Setting; Volume 2, Hydrology; Volume 3, Meteorology, Air Quality, and Noise; Volume 4, Ecology; and Volume 5, System Interrelationships.

The objective of Volume 1 is to place the two-year baseline study on Tract C-b into a regional and historical perspective. In this perspective the geologic Piceance Basin is differentiated from the drainage of Piceance Creek which is termed the Piceance Creek basin.

The results of the baseline study have pointed out the interactions that exist between the major environmental parameters in each study area. For example, the present form and hydrology of the Piceance Creek basin is discussed in relationship to the geology of the region as well as the continental, regional, and local climatology. Climate is seen to be a function of time and also of surface form, which has been shaped by climatological factors. Throughout the course of the baseline study disciplinary interactions can be observed.

Each chapter in Volume 1 is in general a review of the literature available on the subject of that chapter confined within the Piceance Basin. Until recently there has been very little written on the various scientific disciplines as they occur in northwest Colorado. This lack of data has led to generalizations on the specific subjects, and causes problems in assessing the baseline vis-a-vis the regional and temporal background. In particular, reference is made to stream flow which apparently has increased by 100 percent since the Rio Blanco nuclear test.

The historical and regional study of the physical sciences includes geology, climatology, hydrology, and soils. Site specific data collected over the baseline period are presented in the volumes appropriately related to these study areas. Hypotheses developed upon the basis of the present information will perforce be modified as monitoring programs continue.

Biological studies over time indicate that variations in vegetation composition have occurred due to grazing of cattle and sheep as well as chaining activities of the Bureau of Land Management in an attempt to improve rangelands. Wildlife variations have occurred as a result of these changes in vegetation as well as hunting and eradication activities of man.

The historical, cultural background of the Piceance Basin is in some respects as sketchy as the knowledge of the physical environment. Prior to the middle-late 1800's little is known about human habitation in northwest Colorado. Since about the turn of the present century the cultural environment is fairly well documented. During the last half of the 19th century railroads, herding, and mining have contributed to the growth of the area. Although the economic fortunes and the population have fluctuated over the past 70 years, the present inhabitants look forward to improving the economic base of the Piceance Basin in such a manner as to preserve the natural and cultural environment that originally drew them or their ancestors to this region.

2.1 Physiography and Geology

2.1.1 Introduction

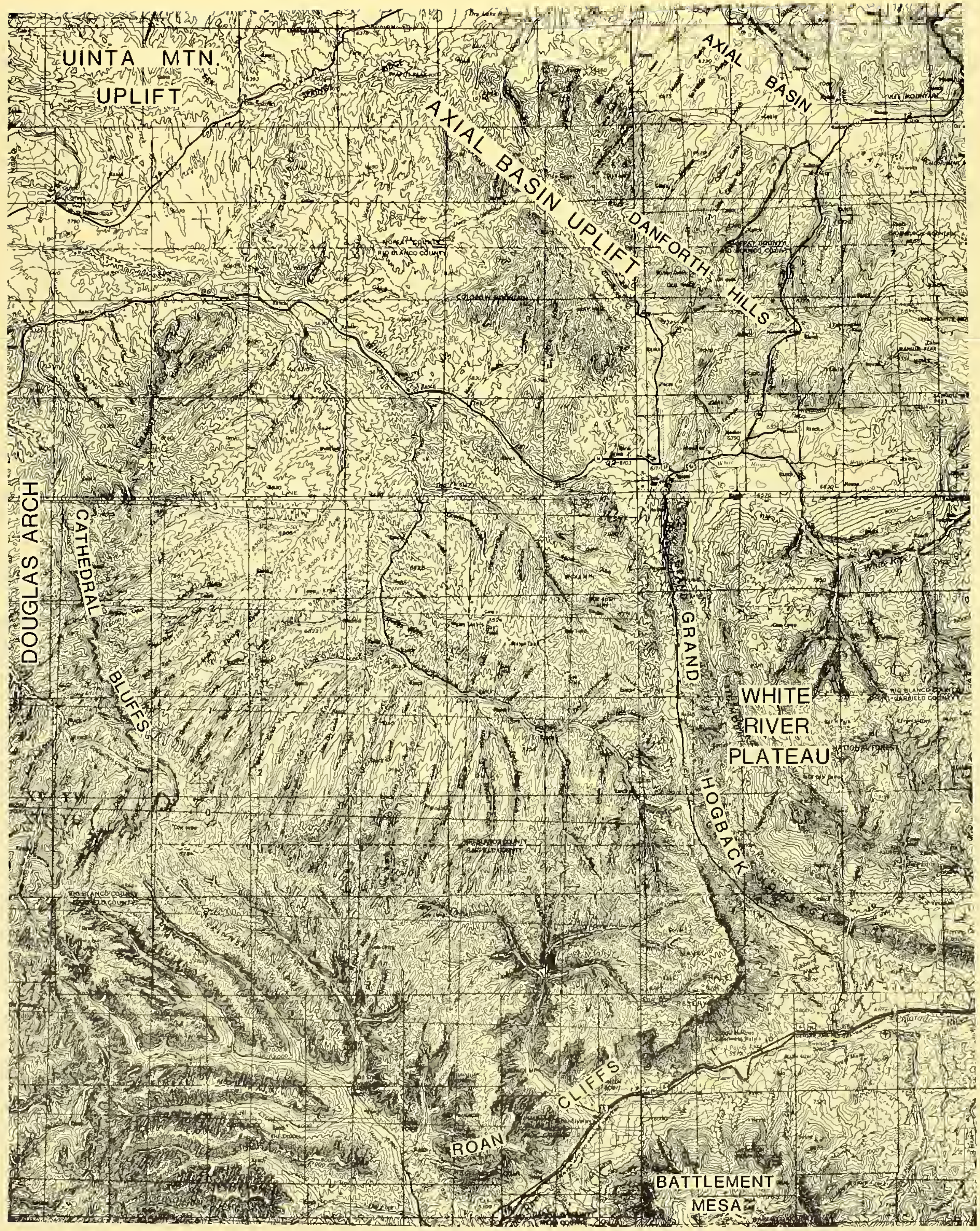
The physiography of northwestern Colorado may be described by the following units: Southern and Middle Rocky Mountain Provinces, the Wyoming Basin Province, and the Colorado Plateau Province (Fenneman 1931). The Southern Rocky Mountain Province includes the White River Plateau, the Elk Mountains, and the West Elk Mountains. It is connected on the north to the Middle Rocky Mountain Province (Uinta Mountains) by the Axial Basin Uplift and associated hills and mountains (Danforth Hills trend). This connection serves to separate the Sand Wash basin of the Wyoming Basin Province from the Piceance Creek basin which is a major structural feature on the Colorado Plateau. Figure 2-1 shows these main features and the physical and geographical setting of Tract C-b.

2.1.2 Historical Geology

The early historical geology of the region is one of long periods of deposition interrupted by regional uplift and widespread erosion. This early sequence of deposition, uplift, and erosion continued until prominent tectonic elements developed during the Pennsylvanian time period. By late Pennsylvanian deposits characteristic of the period, evaporities and red clastics, were widespread. This depositional environment was maintained on into the Permian with deposition of red arkosic conglomerates and sandstones. Sea level oscillations with the attendant change in areas of erosion and deposition continued through the Jurassic and into the Late Cretaceous.

At the end of the Cretaceous and during the Tertiary, Laramide and post Laramide orogeny and epeirogeny formed structural features observed today. It is the Tertiary and later history that is most relevant to the Oil Shale Tract and to the present form of the Basin.

During the Eocene period the extensive oil shales of the Green River Formation were deposited in structural depressions within which formed Lake Uinta and other basins. Post Eocene structural deformation was most intense. Epeirogenic uplift caused streams to cut through extensive, nearly horizontal basalt flows into the



TOPOGRAPHIC MAP OF PICEANCE CREEK BASIN

FIGURE 2-1 WITH MAJOR PHYSIOGRAPHIC FEATURES

underlying early Tertiary Green River and Wasatch Formations and Upper Cretaceous Mesaverde. Broad gentle uplift through the Quaternary created the structural altitude and presented the uplifted surface by which subsequent erosion has sculptured the present form of the Piceance Basin. Five thousand feet of downcutting produced steep cliffs and narrow canyons that typify the southern border of the basin.

2.1.3 Stratigraphy

2.1.3.1 Introduction

The C-b Tract is near the center of the Basin in which rocks of many ages have been deposited. Rocks of the Wasatch, Green River, and Uinta Formations are exposed along the Basin's periphery and downwarped so that older beds are deeply buried. It is the rocks of the Green River Formation (Eocene), and younger Uinta Formation, that are of primary importance; the outcrop of the Green River Formation defines the area of regional interest. These two formations of Eocene age encompassing three lithologic zones are pertinent to the geology of the Tract. The three major lithologic zones are a basal fresh water shale (the Garden Gulch member), a middle dolomitic oil shale and associated saline deposits (the Parachute Creek member), and an upper clastic unit (Uinta Formation) (Figure 2-2). Alluvial deposits of varying thickness are found in the major stream valleys and up the larger draws, undifferentiated alluvial-colluvial deposits are found on valley side slopes and on the divides.

2.1.3.2 Tertiary Deposits

The Uinta Formation lies just below the gravel capped surface and forms the surface bedrock of the central Piceance Creek basin. All the surface outcrops on the Tract are Uinta and it crops out extensively on Piceance Creek and forms a broad upland plateau over most of the area. This unit consists mostly of light-brown and gray, silty sandstone, and tan to gray carbonaceous siltstone, with lesser amounts of marlstone and shale. In general, the marlstones are barren or contain only small amounts of organic material; however, oil shale beds up to 30 feet thick have been reported from drill cuttings. Throughout the Uinta Formation there is much lateral variability in lithology and, except for some of the thicker marlstone units, most beds cannot be correlated over any significant distance. The original thickness of this unit cannot be determined because erosion has removed the upper part. However, the Formation reaches a maximum thickness of more than 1500 feet in the north central part of the basin.

The Green River Formation, which contains 3500 feet of saline

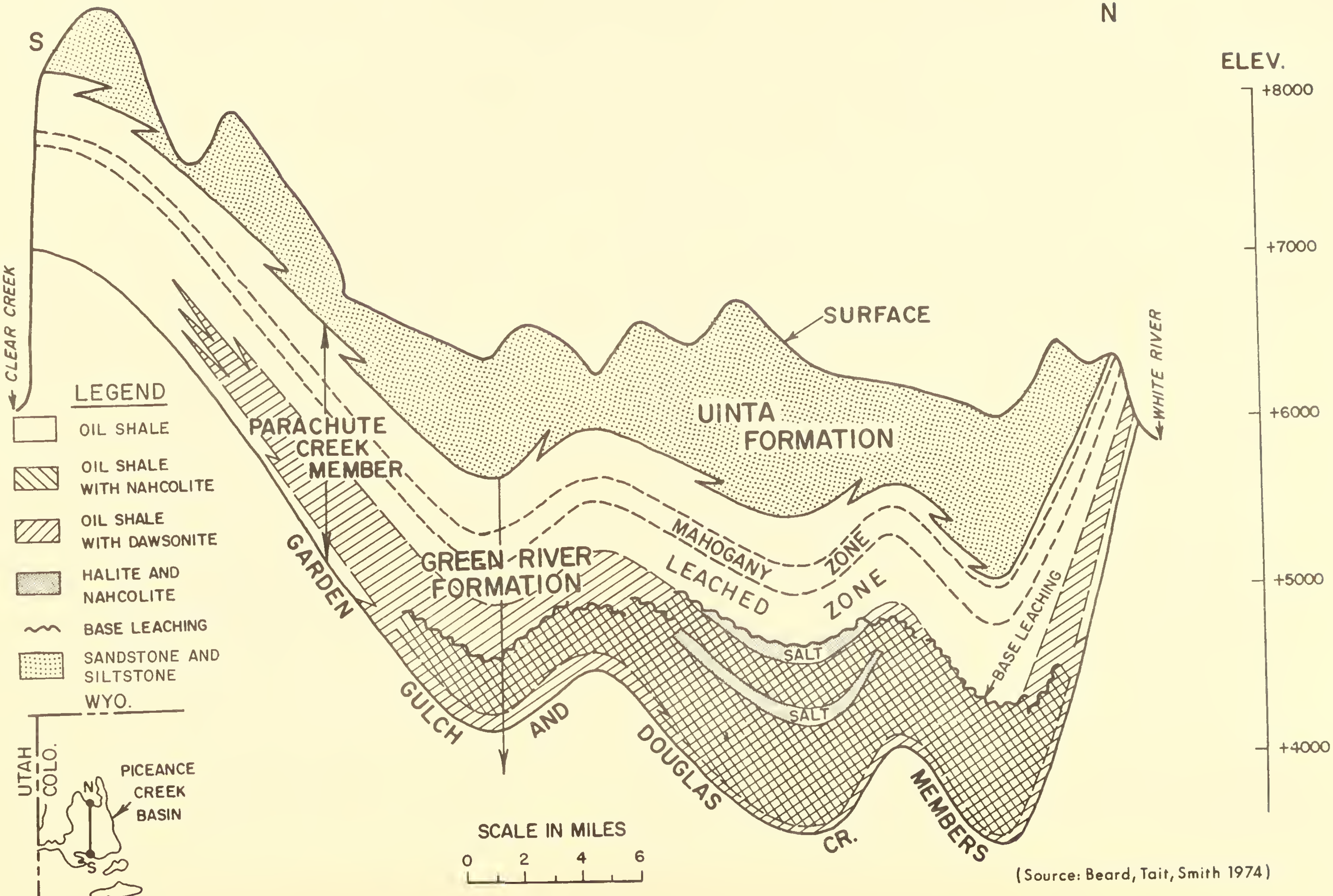


FIGURE 2-2

S-N DIAGRAMMATIC CROSS SECTION THROUGH PICEANCE CREEK BASIN

lacustrine rocks, evaporates, and the oil shale deposits, comfortably overlies the Wasatch Formation of Paleocene and Eocene ages. The Green River is divided into several lithologic units based on its depositional history. Bradley (1931) originally divided the Green River Formation into four members, here listed in stratigraphically descending order: Evacuation Creek, Parachute Creek, Garden Gulch, and Douglas Creek. However, Cashion and Donnell (1974) recently revised Bradley's nomenclature with the result that the name Evacuation Creek member of the Green River Formation has been abandoned, and these rocks are now placed in the lower part of the Uinta Formation. This change in nomenclature removes this strata of the desiccating stage of Lake Uinta from the lacustrine succession that comprises the Green River Formation (Roehler 1974).

With a gradational contact at its top and considerable interspersing of oil shales, barren marlstones, and less frequently sandstones and siltstones, the top of the Green River Formation is selected at the highest oil shale horizon. This upper stratigraphic unit is called the Parachute Creek member.

The Parachute Creek member of the Green River Formation is composed almost entirely of organic-rich marlstone (oil shale). It ranges in thickness from less than 900 feet around the southern and western margin of the basin to more than 1900 feet in the north-central part of the basin. The richness of the Parachute Creek oil shales varies both vertically and laterally and this member may be subdivided into a number of units based on richness and other properties. Around the margin of the basin, rich oil shale (greater than 25 gallons per ton (GPT) is restricted to a unit in the upper part of the member, about 100 feet or less in thickness, called the Mahogany zone. This rich unit persists over most of the basin. The Mahogany zone generally thickens toward the north-central part of the basin; it reaches a maximum thickness of more than 200 feet.

Oil shale in the lower part of the Parachute Creek member (below the Mahogany zone) is best developed in the north-central part of the basin. This organic-rich marlstone, which has been referred to as the Lower Rich zone, reaches a maximum thickness of about 1200 feet and has a maximum richness in excess of 30 GPT near the basin depocenter. Rich oil shale units in the Lower Rich zone thin and grade laterally to leaner oil shale toward the margin of the basin. At the outcrop, the Lower Rich zone averages less than 10 GPT.

In addition to these two significantly thick rich shale zones, there are numerous thin bands of rich oil shale with grades exceeding 30 gallons per ton. The more persistent have been named "the Big Three," "Stillwater Zone," and "Four Senator's Zone."

In the north-central part of the basin, the Lower Rich zone contains large amounts of the saline minerals nahcolite ($NaHCO_3$),

dawsonite ($NaAl(OH)_2CO_3$), and halite (NaCl). In the vicinity of the basin depocenter the nahcolite-bearing section is present over an interval up to 900 feet thick, which averages as much as 28 percent nahcolite by weight. Nahcolite (generally) occurs as coarsely crystalline radiating nodules one to three inches in diameter, but occasionally is found in beds. The nahcolite-bearing oil shales decrease in thickness and nahcolite content toward the margin of the basin (Figure 2-3). Halite is mostly concentrated in two zones about 250 feet apart. The "upper salt zone" has a maximum thickness of about 160 feet and the "lower salt zone" has a maximum thickness of about 120 feet. Both salt zones are comprised of varying amounts of interbedded halite, nahcolite, and oil shale. The salt zones, which are much more restricted in lateral extent than the nahcolite-bearing section, thin and pinch out toward the basin margin (Figure 2-2). Dawsonite is generally confined to the interval between the base of the "upper salt zone," or its stratigraphic equivalent, and the base of the Parachute Creek member. Dawsonite normally occurs as minute crystals, five microns or less in size, disseminated throughout the oil shale. Over small intervals dawsonite may comprise as much as 25 percent of the rock by weight, but over wide intervals concentrations generally average 10 percent by weight or less. Dawsonite diminishes or disappears toward the margin of the basin owing to nondeposition.

The beds between the nahcolite-bearing section and the lower part of the Mahogany zone are commonly referred to as the "leached zone." The leached zone is characterized by solution cavities, open fractures, local breccias and intervals of porous, earthy marlstone. Substantial quantities of nahcolite, which were originally present in this interval, have been dissolved and removed by ground water. Leached zone rocks (generally) are highly porous and permeable.

Distinctive markers in the Parachute Creek are the Mahogany marker, the "A" Groove, and the "B" Groove. The Mahogany marker is a 6 to 12 inch series of ash and tuff beds found to be persistent throughout the basin. It is five feet above the mine roof and is thus used as a datum for stratigraphic correlation.

The "A" Groove is a 15 foot-thick barren marlstone, 30 feet above the Mahogany marker. It is easily detected on geophysical logs. The 20 foot thick "B" Groove is also a barren marlstone approximately 150 feet below the Mahogany marker and is easily distinguished on geophysical logs.

The 180 feet between the bottom of the "A" Groove and top of the "B" Groove is the Mahogany zone. The top 30 to 40 feet just below the Mahogany marker is extremely rich and is known as the Mahogany ledge from its characteristic weathered form at the outcrop. Curiously, the richer the oil shale the more resistant to weathering the marlstone becomes. Hence the persistent barren marlstone units above and below the Mahogany zone weather out as indentations in the vertical profile or as "grooves." The Mahogany, on the other hand, forms part of a cliff. Some of these cliffs are as high as 2000 feet above a stream.

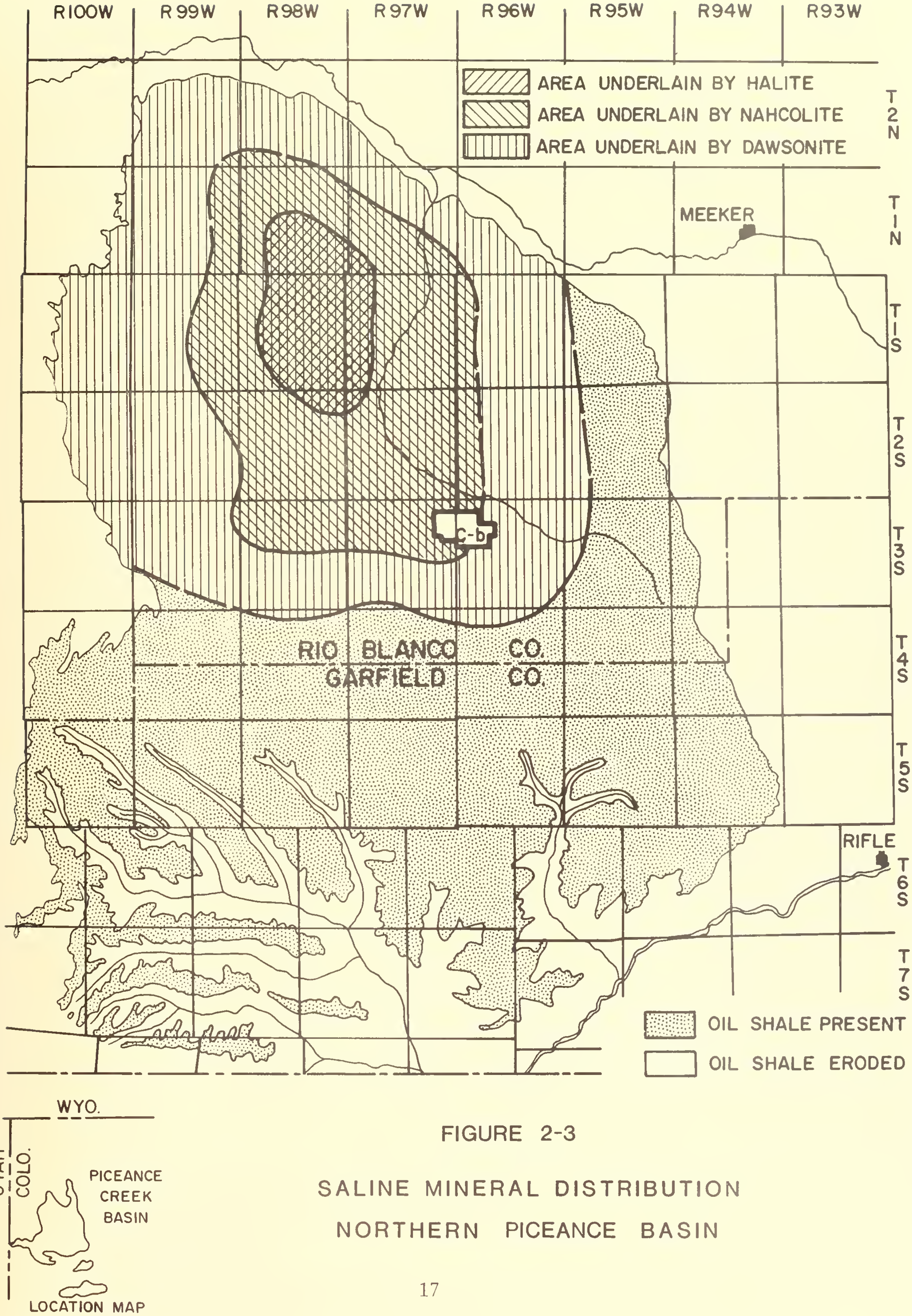


FIGURE 2-3

SALINE MINERAL DISTRIBUTION
NORTHERN PICEANCE BASIN

The Garden Gulch and Douglas Creek members underlie the Parachute Creek member. Because the criteria used to define the boundary between these two members at the outcrop do not apply in the subsurface, these members are usually combined in regional geologic discussions. Deposited in a deep moderately saline lake that occupied the entire Piceance Creek basin and adjoining areas, the Garden Gulch and Douglas Creek members are chiefly composed of fine-grained clastic rocks. In the central part of the basin, the lower part of the combined unit is composed of black oil shale, interbedded mudstone, siltstone, and clay (illite) shale. The amount of clay shale gradually increases upward through this part of the section, and in the upper part of the combined section, it is interbedded with moderately rich oil shale. The two members have a combined thickness ranging from 300 feet near the center of the basin to more than 1000 feet in places along the outcrop. The thickening of the combined unit toward the outcrop is attributed to the additional amounts of silt and sand that have been added to the section. The Garden Gulch is relatively impermeable and forms the lower boundary of the aquifer system.

2.1.3.3 Recent Deposits

Recent deposits include alluvium in the stream valleys and draws as much as 140 feet thick, colluvial deposits and mass wasting deposits on the slopes, and eolian deposits. For the most part the source for the recent deposits is the Uinta Formation.

Alluvial deposits are found in all major valleys and at varying distances up tributary valleys. The amount of material and the distance up the tributary depends upon the size of the tributary and the local structure. In addition to the sands and gravels found in the floodplain along streams, other alluvial materials are found in the fans which are localized ungraded deposits of sand, gravel, and larger debris confined to those areas where tributaries empty into their master stream. Many small fans are found along tributary valleys. Because of the steeper slopes and more narrow bases, these fans in tributary valleys might be more accurately described as alluvial cones. Interestingly, almost all of the alluvial fans on Piceance Creek in the vicinity of the Tract--and certainly the largest deposits--are on the north side of the river.

Colluvium, unconsolidated materials that have been transported downslope by gravity or slopewash, are found on valley sides or at the base of the slope. Depending upon the velocity with which they are transported downslope, these unconsolidated deposits may be carried some distance out onto the floodplain. Some materials described as colluvial have been mapped high on valley walls and in swalls on the uplands. These are interesting by their topographic position and additional study could prove valuable in reconstructing the paleoenvironment of an area.

Eolian deposits are those materials transported by the wind. With the lack of vegetative cover and windiness of the basin, such a geomorphic process is common. However, the scale of this process is unknown and no extensive deposits of eolian material have been mapped.

2.1.4 Structural Geology

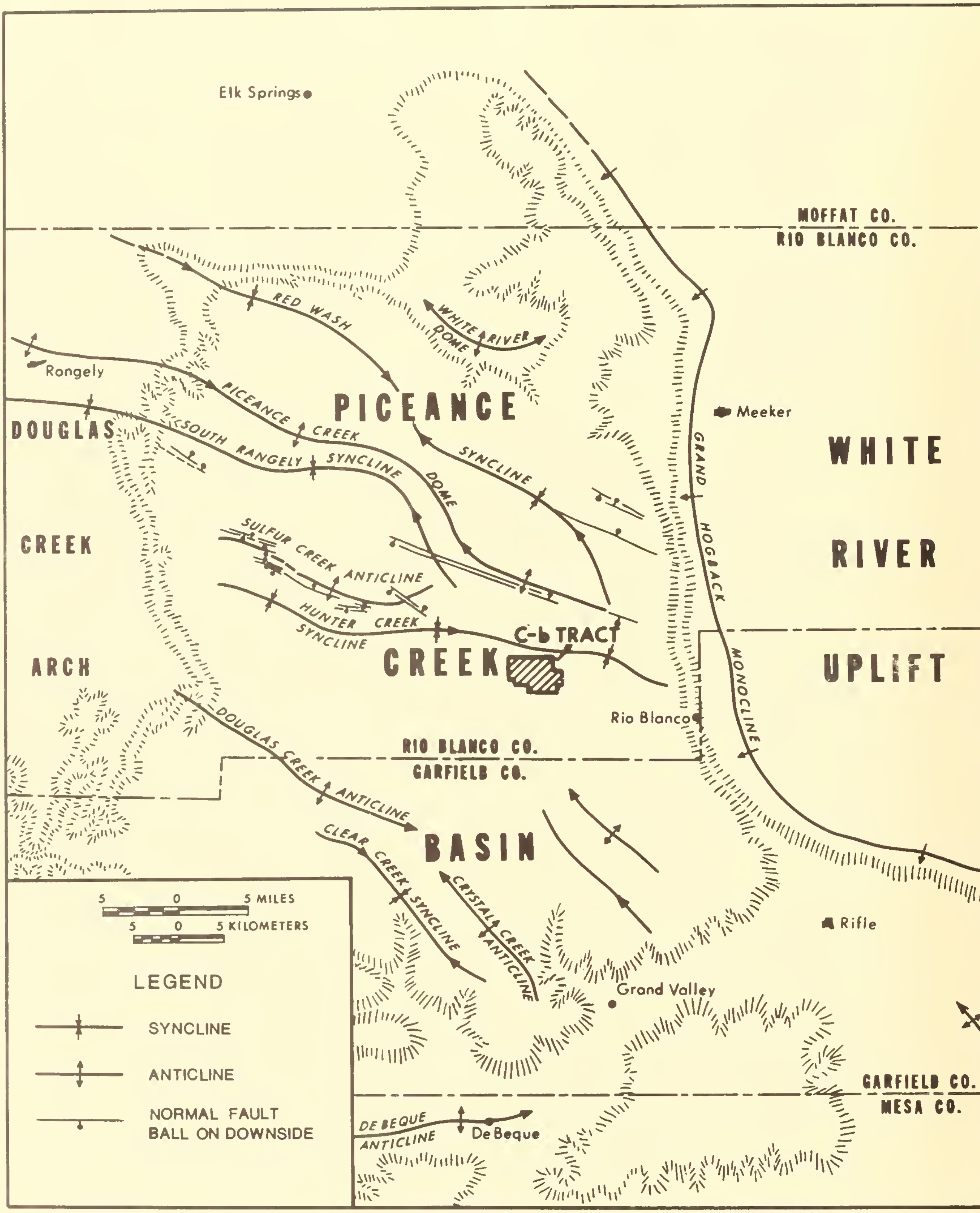
The Piceance Creek basin is a NW-SE trending structural and sedimentary basin. Total structural relief is greater than 3500 feet. The basin is a relatively simple structural downwarp. It is asymmetrical with the steepest dips on the northern and eastern sides. Relatively low dips are present elsewhere and rarely exceed 5^{o}. Several anticlinal folds are superimposed on the smooth regional contour. These folds generally have a northwesterly or westerly trend and parallel the major structural elements which border the region.

The major subregional structures in the Piceance Creek basin are the White River dome, Red Wash syncline (structurally the deepest part of the basin), Piceance Creek dome, Rangely anticlinal trend, south Rangely syncline, Sulfur Creek anticline, Hunter Creek syncline, and Douglas Creek and Crystal Creek anticlinal trend. (Figure 2-4.) These structural features achieve a certain amount of topographic expression in that the synclines are often expressed as valleys and the anticlines as ridges. (Compare Figures 2-1 and 2-4.)

Many of the subregional anticlines are faulted. The faults are subparallel to the axes of the structures and commonly occur in pairs forming narrow grabens. Faults are generally steeply dipping normal faults. Persistence of faults appears to be one to ten miles on a strike of N70^{o}-80^{o}W. Evidence for faults on the Tract is not conclusive; no significant faults are known to exist on the Tract. The nearest known faults are on the Sulfur Creek anticline two miles northwest of the Tract and on Piceance Creek anticline three miles north.

The basin is extensively jointed and fractured. A well developed natural fracturing and jointing system is evident in the Uinta sandstones and siltstones on and around the Tract. Most features have a westerly or northwesterly trend, although significant jointing occurs at right angles to the major direction. Joint sets were measured at 39 locations that were fairly evenly distributed across the Tract. There were two dominant sets; one set striking N72^{o}W and dipping vertically and one set striking N75^{o}W and dipping 66^{o} to the north. Minor joint sets are not equally developed in all stratigraphic zones. Jointing appears to control the orientation of many streams. Piceance Creek is the largest stream and parallels the dominant fault direction N70^{o} to 80^{o}W.

The terrain of the C-b Tract and vicinity is characterized by gulches and the origin of these may be attributed to faulting or



ADAPTED FROM MURRAY & HAUN P. 25 (1974)

FIGURE 2-4 TECTONIC MAP OF PICEANCE CREEK BASIN SHOWING SELECTED STRUCTURES

fracture since the strike orientation of the gulches is subparallel or orthogonal to the dominant structural trend. However, with regard to the gulches striking N to N21^{O}E, the drainage may also be thought of as developing naturally on the dip slope of the basin, i.e., consequent streams subsequently modified by structural control. Core analysis indicates a significant increase in fracturing beneath Scandard Gulch and the abrupt change in direction of drainage ways on the Tract may be because of structural controls.

2.1.5 Geomorphology

The structural Piceance Basin is of much greater extent than the stratigraphic and hydrographic Piceance Creek basin. The stratigraphic basin is the more specific area of interest for oil shale and it is generally defined by the outcrop of the Green River Formation.

The Piceance Basin in general is an elevated area that is part of the Colorado Plateau Physiographic Province. It is found between the Colorado River on the south and the White River on the north and it owes its topographically high position on the south to structural altitude and to aggressive erosion by tributaries of the Colorado River. This regionally elevated area (plateau) contains the richer oil shale deposits and thus has been the focus of exploitation and exploration for sporadic oil shale activity during the past half century. It is bound on the north by the White River (and White River-Skull Creek anticlinal trend), on the east by the Grand Hogback (and White River Uplift), on the south by the Roan Cliffs and the Douglas Creek Anticline, and on the west by the Cathedral Bluffs (and Douglas Creek Arch). The southern and highest part (elevation 9286 feet, west of Rifle) is deeply and intricately dissected by tributaries of the Colorado River, and it terminates in an irregular line of precipitous cliffs. Elsewhere the outward facing escarpment is more regular and less steep. Erosion working northward in the plateau has separated the structural Piceance Basin into two hydrologic and topographic basins, i.e. the Piceance Creek basin and the tributaries to the upper Colorado River. (Figure 2-5.)

The upland surface of the Piceance Creek topographic basin slopes gently away from the Roan Cliffs and the topographic divide between the Piceance drainage to the north and the Roan and Parachute Creek drainage to the south. This upland, the Roan Plateau, is rugged away from the divide to the north with local relief from ridge top to stream running as high as 650 feet. To the south valley walls are steep and approach the vertical toward the tributaries of the upper Colorado; relief exceeds 2000 feet. Side slopes of the Piceance Creek tributaries approach the vertical locally where a particularly resistant sedimentary bed crops out.

Drainage patterns along the divide differ north and south

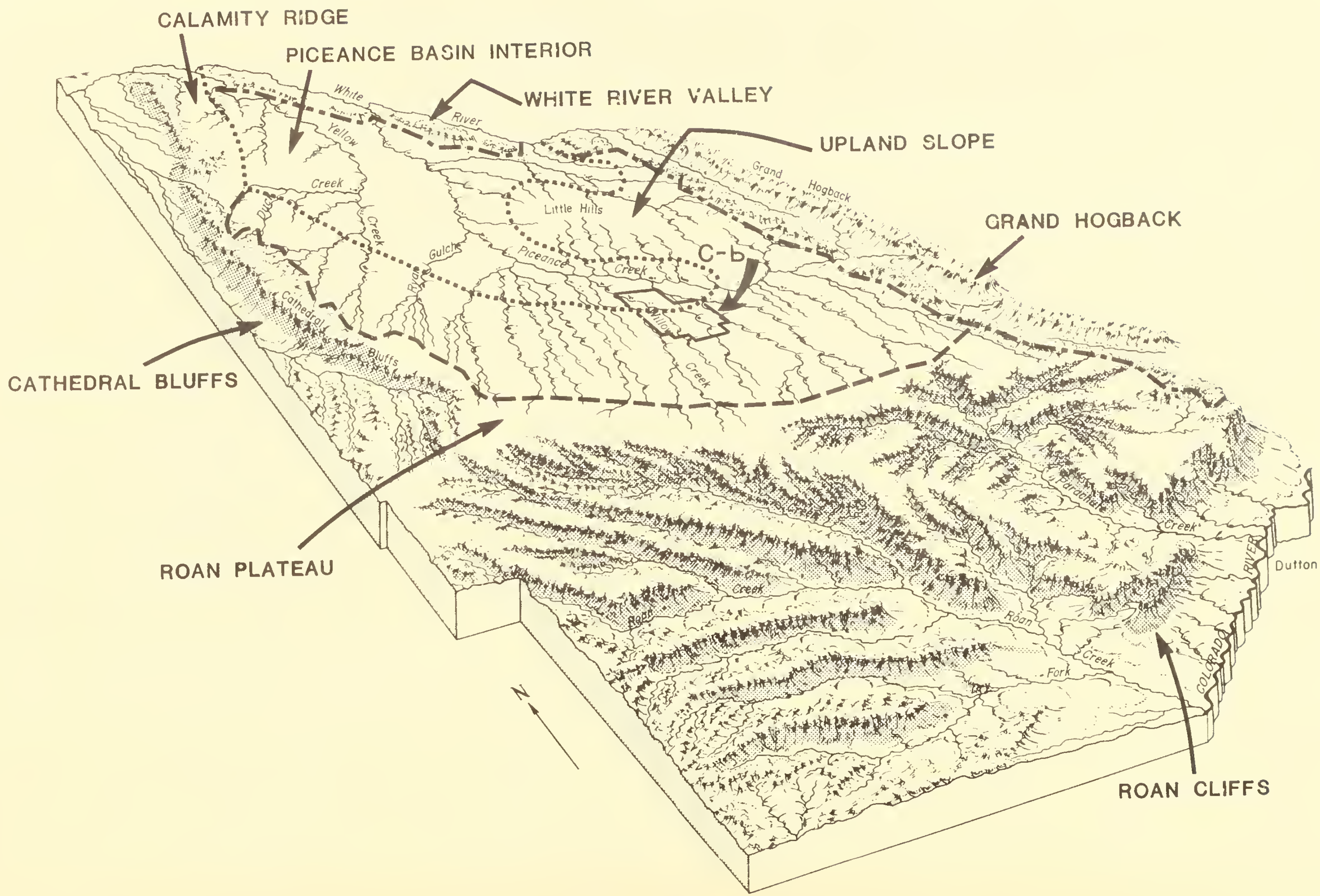


FIGURE 2-5

GEOMORPHIC MAP PICEANCE BASIN

(Source: USGS Hydrologic Investigation Atlas HA-370)

from the crest. The drainage pattern established by the tributaries to Piceance Creek and to Yellow Creek, as they worked headward to the edge of the Plateau, is a radial subparallelism. That is to say the upper reaches of the tributaries are parallel to subparallel, and as they encroach on the curved, concave, southern and western edge of the plateau, they form a radial pattern with the locii of the radii being centered on the White River in sections 4 and 9 of Township 1 North, Range 96 West (26 mile radius). This interesting pattern does not continue south of the divide into the drainage of the Colorado River where the patterns developed by Parachute Creek and Roan Creek are classically dendritic; nor does it continue toward the north on any one tributary for over 10 miles.

For many of the tributaries the deviation from this radial subparallelism occurs at about eight miles toward the basin interior. On the west side of the basin this occurs at the 7000 foot level in the vicinity of Calamity Ridge. This change occurs approximately on the 6500 foot contour through the center of the basin and terminates along Piceance Creek beginning at 7000 feet elevation.

The main drainages of Piceance Creek and Yellow Creek show the major structures of Piceance Creek dome and Rangely anticline. As each stream bends around the basinward plunge of the respective structure, it forms an interfluvial area with 500 feet of relief on the Piceance Creek side and 300 feet of relief on the Yellow Creek drainage. Both stream valleys are asymmetrical with the steeper side slope toward the common interfluve.

The drainage patterns and erosion features tend to develop areas of similarity. Without going into the processes that were involved (requiring an investigation that is beyond the scope of this report) these areas can be divided as follows:

1. Roan Cliffs and Roan Plateau on the south

2. Cathedral Bluffs and Calamity Ridge on the west

3. Grand Hogback on the east

4. White River valley on the north

5. The upland slope of Piceance Creek basin terminating at Calamity Ridge area on the northwest and at Piceance Creek on the east. This is an area beginning on the 8000 foot contour where the terrain consists of a series of subparallel ridges and valleys with local relief of as much as 500 feet. The ridges are relatively broad and convex and slope northward at 120 feet per mile. The larger the tributary the wider the floor, but most drainages are V-shaped. The gradient of the larger drainages approximates

that of the ridges but minor drainages are considerably steeper.

6. The basin interior containing the valleys of Piceance Creek and Yellow Creek with the drainage patterns forming about Piceance Creek dome and Rangely anticline. Main valleys are flat bottomed, fairly narrow, and steep sided. The valley floors are covered with varying thicknesses of alluvium. Drainageways tend toward assymmetry with the right-hand valley wall being steeper and more heavily gullied except where Piceance Creek curves to the northwest around the plunge of Piceance Creek dome. Here the left-hand valley wall is steeper. This region can be divided into the Piceance Creek hydrologic basin and the Yellow Creek hydrologic basin. Upland slopes are somewhat less in the Yellow Creek basin. Stream gradients in both areas approximate the upland slopes except for minor drainages and gullies.

These six areas can be thought of as geomorphic subregions of the Piceance Basin. Tract C-b is located on the boundary between the upland slope and basin interior subregions with the greatest part of the Tract in the upland.

2.1.6 Study Area

2.1.6.1 Topography and Geology

Centered on the C-b Tract the study area extends seven miles east-west and eight miles north-south at the widest point and covers 44 square miles (Figure 2-5). The study area is topographically part of Piceance Creek basin, a major structural feature in the Colorado Plateau. It is transected by Piceance Creek which flows in a west-northwest direction. Drainage and regional slope in the southern part of the area are to the north and northeast and in the northern one-third of the area drainage and regional slope are to the south and southwest.

Piceance Creek and larger tributaries are incised into the regional surface with topographic relief near streams ranging from 300 feet to 500 feet. South of Piceance Creek the area is characterized by narrow, steep-walled, flat-bottomed valleys separated by broad interfluves whose flat-to-gently rolling surfaces are inclined to the north. North of Piceance Creek the topography differs; although the major tributary valleys are steep-walled and flat-bottomed the interfluvial areas are dissected into narrow ridges and steep drainage ways.

2.1.6.2 Stratigraphy

The Tract is located in the southeast part of the Piceance Creek drainage system. The Tract contains a sedimentary sequence that is intermediate between the section present at the outcrop and the section near the basin depocenter. Surface exposures of bedrock within the study area are Eocene sandstones and siltstones and unconsolidated Quaternary deposits. The Eocene includes the sandstones and siltstones of the Uinta Formation and the three members of the Green River Formation which consist of dark shales, marlstones, and thin-bedded sandstones, siltstones, and limestones.

The Uinta Formation comprises the surface bedrock over the entire C-b Tract. This unit, which consists mostly of interbedded sandstone, siltstone, and marlstone, ranges from about 400 to 900 feet in thickness across the Tract. Figure 2-6 is a surface geology map of the Tract and surrounding area showing key units in the Uinta Formation.

The Parachute Creek member of the Green River Formation underlies the Uinta Formation. Composed almost entirely of organic marlstone (oil shale) of varying richness, this unit averages about 1600 feet in thickness beneath the Tract. As shown in Figure 2-7, the Parachute Creek member has been subdivided into a number of units based on richness differences and other physical properties.

Until recently the uppermost member of the Green River Formation (the Parachute Creek) was not recognized in surface outcroppings within the study area. Newly proposed changes in nomenclature and recently acquired knowledge regarding facies changes and the lateral extent of the marlstones of the Green River Formation allow the description of an outcropping of upper Green River (Parachute Creek) marlstone within the study area but not on the C-b Tract itself.

The Garden Gulch and Douglas Creek members underlie the Parachute Creek member. These units, which are not differentiated on the Tract, have a combined thickness of about 500 feet. The Garden Gulch-Douglas Creek members are mostly comprised of interbedded true shale and organic marlstone. Some poorly developed siltstones and sandstone are present near the base of this combined unit.

The contact between the Green River Formation and the overlying Uinta Formation is gradational with the marlstone of the Parachute Creek member interfingering with the sandstones and siltstones of the overlying Uinta. The sandstones of the Uinta Formation are thin-to-massive and quite lenticular. They exhibit rapid thickening, owing to channeling into underlying units, and rapid thinning and lateral pinchout. Being more resistant to weathering and erosional forces than the adjacent siltstones, they often

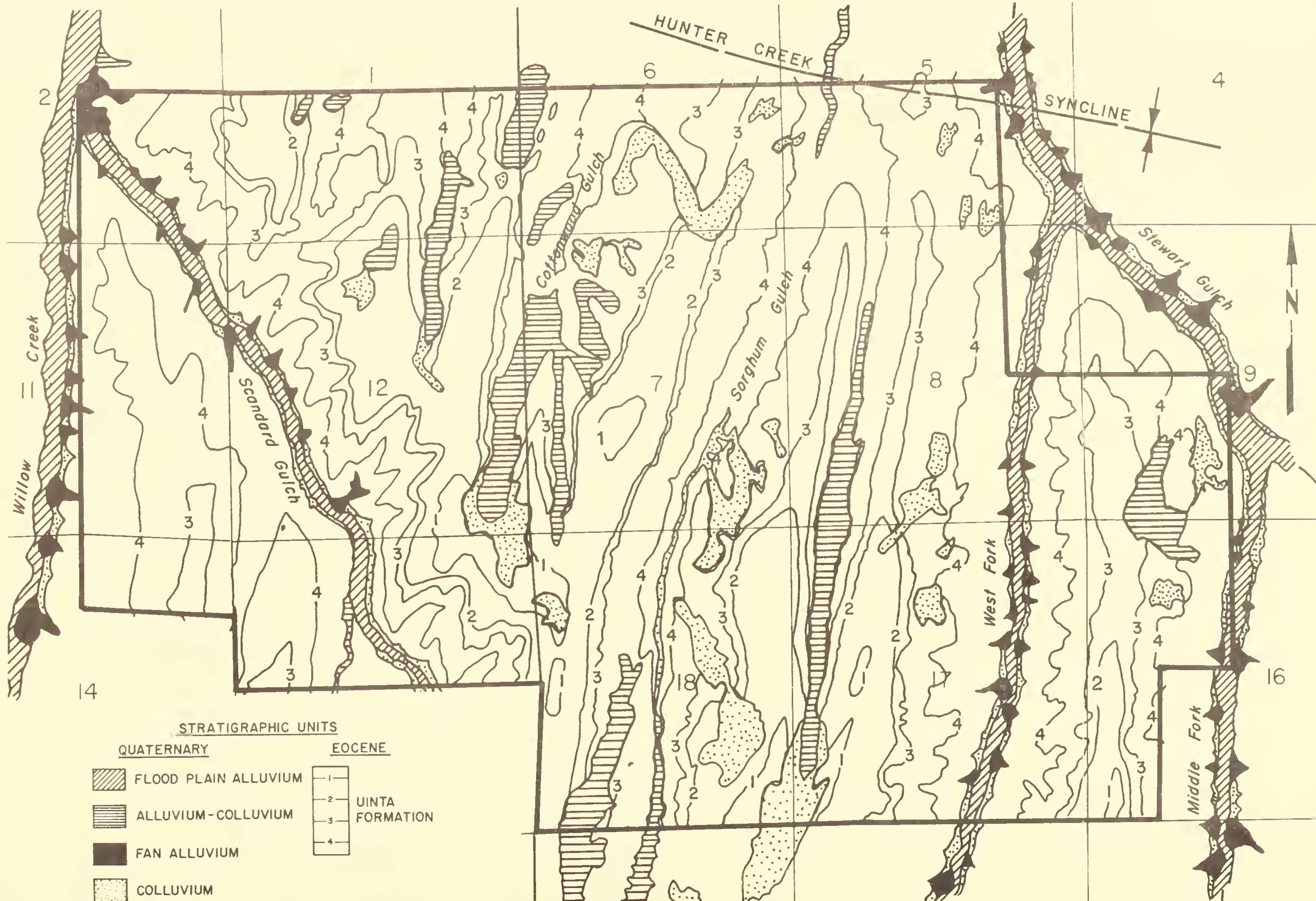


FIGURE 2-6

SURFACE GEOLOGIC MAP
TRACT C-b AND VICINITY

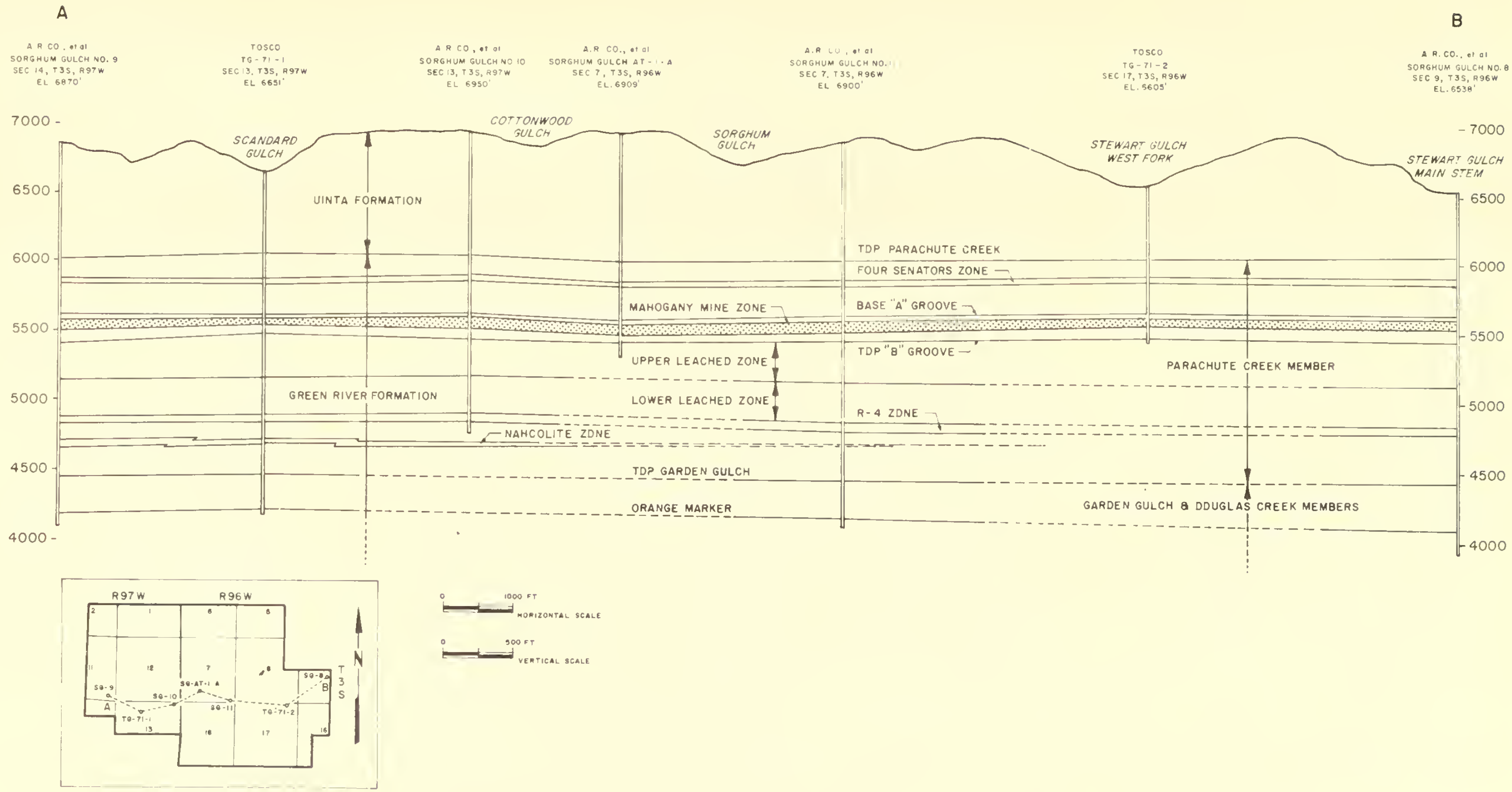


FIGURE 2-7

EAST-WEST STRATIGRAPHIC CROSS SECTION
TRACT C-b

form prominent outcroppings. Their lenticularity limits their usefulness as mapping units over the study area. However, ten possible mapping horizons were located on airphotos and subsequently located and described at the outcrop. Five mappable units were defined on the Tract itself (Figure 2-6) and one sandstone, Unit 3, was found to be persistent throughout the C-b Tract and thus useful as a surface mapping and correlative horizon. The unit was named the Scandard Gulch sandstone after the good exposures formed along the eastern side of Scandard Gulch. This yellow-brown, fine-to-medium-grained sandstone ranges in thickness from 30 to 40 feet. It exhibits cross-bedding and often is conglomeratic at the base. At the outcrop it commonly forms a cliff 4 to 15 feet high, which in turn forms a rimrock that can be traced around the upland surface of the C-b Tract. At the base of this unit the cliff form gives way to the more gentle slope of the underlying siltstone, Unit 4.

A second sandstone, Unit 1, though unnamed was found to be a good mapping horizon in the southern part of the Tract. Unit 2, a siltstone, forms the undulating upland surface of the Tract and overlies the Scandard Gulch sandstone. A secondary cliff form underlies Unit 4 and is exposed in the northern part of the Tract. It has been informally called the "Cannonball Sandstone" because of the many spherical concretions which have weathered out of it. Its base is not exposed within the project area.

Quaternary deposits were identified as stream alluvium, alluvial fans, colluvial deposits, and mixed alluvium and colluvium. Stream alluvium is present in narrow bands along the main drainages overlying the Uinta Formation. The thickness of this alluvial veneer is generally less than 100 feet. It forms the flat-bottom floors of Piceance, Hunter, and Willow Creeks and Stewart Gulch and is found to some extent up Scandard Gulch. Alluvial fan deposits occur where tributaries enter the larger valleys. The number of fans is large but the individual area extent is quite small. Colluvial deposits occur on the uplands and the base of valley walls between alluvial fans. The alluvium-colluvium mapping unit covered areas where the depositional agent of unconsolidated deposits was unknown. Thick accumulations of alluvium-colluvium can be found in upland areas; where they occur in the upper reaches of the draws or on steep slopes, they are unstable particularly to the passage of large amounts of water.

2.1.6.3 Structure

The study area lies west of the structural axis of the Piceance Creek basin, as mapped on top of the Mahogany zone (Green River Formation), and on the south monoclinal limb of the Hunter Creek syncline which trends northwestward across the north edge of the area and lies south of Piceance Creek dome. Dip on the flank of the dome is southward at low angles, four to five degrees. South of the axis of the Hunter Creek syncline, within the C-b Tract, beds

dip one to two degrees to the northeast. Although major faults have been noted to the west and north of the study area, only small faults were mapped within the area studied. These smaller faults, perhaps indicative of a more prominent subsurface structure, were mapped in Sections 8, 15, 16, and 17 of Township 3 South, Range 96 West. Most have reverse displacements ranging from two inches to four feet and are parallel to the primary jointing. They strike N75° - 85°E and dip 55° - 75°N. In Middle Stewart Gulch and East Stewart Gulch faults were mapped that had three and four feet of displacement. Since these faults could not be correlated between drainages, it is supposed that they die out laterally within 2000 feet.

2.1.6.4 Joints and Alignments

Joints and alignments were mapped from photos using such linear features as cliffs, vegetation lines, and drainage lines. These linear features are believed to be related to jointing which appears to be of considerable length. Where measured, they could be traced for over 50 feet. One prominent joint system strikes N72°W, dips vertically (±2°), and has an average density of two feet between joints. North of the C-b Tract and south of Hunter Creek syncline the primary joint system has about the same strike but the dip averages 60° to the northeast. North of the synclinal axis the trends are the same but the occurrence is more random. Measurements were made at 82 joint stations, 49 of which were on or within 600 feet of Tract C-b. The data were reduced and the study area was divided based on the joint trends and dip. These divisions and the most prominent joint trends are:

1. North of Piceance Creek -- N40° - 50°W (30 percent) and N80°W to E-W (17 percent)

2. South of Piceance Creek -- N70° - 80°W (40 percent) and N80°W to E-W (9 percent)

3. C-b Tract -- N70° - 80°W (25 percent), N80° - E-W (24 percent)

The dips of the joint planes become progressively steeper approaching the C-b Tract from the north--from 35° north of Piceance Creek to vertical on the Tract itself.

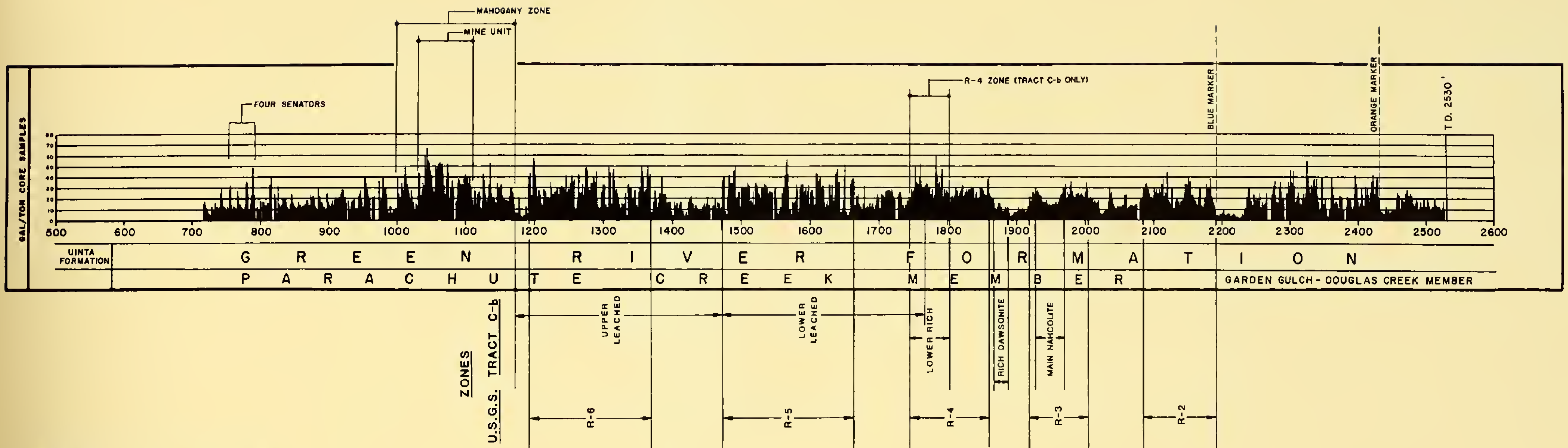
2.1.7 Economic Geology

The Mahogany zone is the unit of principal interest beneath the Tract because it contains the richest oil shale section in this part of the basin. Here, the Mahogany zone ranges from 174 to 187 feet in thickness. As described previously, the Mahogany zone is bounded at the top by the lean oil shale "A" Groove and is bounded at the base by the 20-foot thick "B" Groove.

The oil shale section between the base of "B" Groove and the base of the Parachute Creek member is customarily referred to as the "lower oil shale zone." As previously noted, in the north-central part of the basin this interval is comprised almost entirely of rich oil shale. However, the Tract is peripheral to the basin depocenter and the lower oil shales here are much leaner in comparison to the basin center. Figure 2-8, which is an example log for the Tract, shows the distribution of oil shale richness in the "lower oil shale zone." In general, these oil shale zones are too lean and too intensely fractured to be mined. The R-4 zone appears to be the only interval in the "lower oil shale zone" beneath the Tract with adequate grade and rock quality to have some future commercial potential. However, present plans do not include the mining of this zone. The oil shale resource in the R-4 zone is shown in Table 2-1.

The maximum shale oil resource for the two Major Rich zones on Tract C-b, as indicated in Table 2-1, is 1.52 billion barrels of oil, which is the total of the 77-foot mine zone within the Mahogany zone and the 55-foot R-4 zone below the Mahogany zone. In the "Final Environmental Statement for the Prototype Oil Shale Leasing Program," the total shale oil resource is estimated to be 723 million barrels of oil. The government's figure is apparently based on a conceptual plan to mine a 50-foot unit within the Mahogany zone and a 50-foot unit below the Mahogany zone. Both units are assumed to average 30 gallons of oil per ton.

Both nahcolite and dawsonite are present beneath the Tract. Nahcolite is occasionally found in nodule form within the Mahogany zone, but in such small amounts that it affords no apparent commercial potential. The zone of greatest nahcolite concentration on the Tract is found in the lower part of the Parachute Creek section, about 120 feet below the base of the R-4 zone (Figure 2-9). This nahcolite-bearing interval is present only in the western half of the Tract. It ranges from a maximum thickness of 98 feet in the SG-1 core hole, to six feet in the SG-11 core hole. Just east of SG-11 the zone is absent owing to non-deposition. The amount of nahcolite present within this zone varies from a maximum of 15.4 percent in SG-1 to zero on the east side of the Tract. An estimated 30,000,000 tons of nahcolite are present on the Tract within the main nahcolite zone (Table 2-2). The main nahcolite zone occurs in moderately lean oil shale (i.e., shale that will average on the order of 20 GPT). The low concentration of nahcolite, plus the presence of lean shale, eliminates this zone as an interval of interest in the foreseeable future. Nacholite is also present in small amounts in the R-4 zone on the west side of the Tract (Figure 2-9).



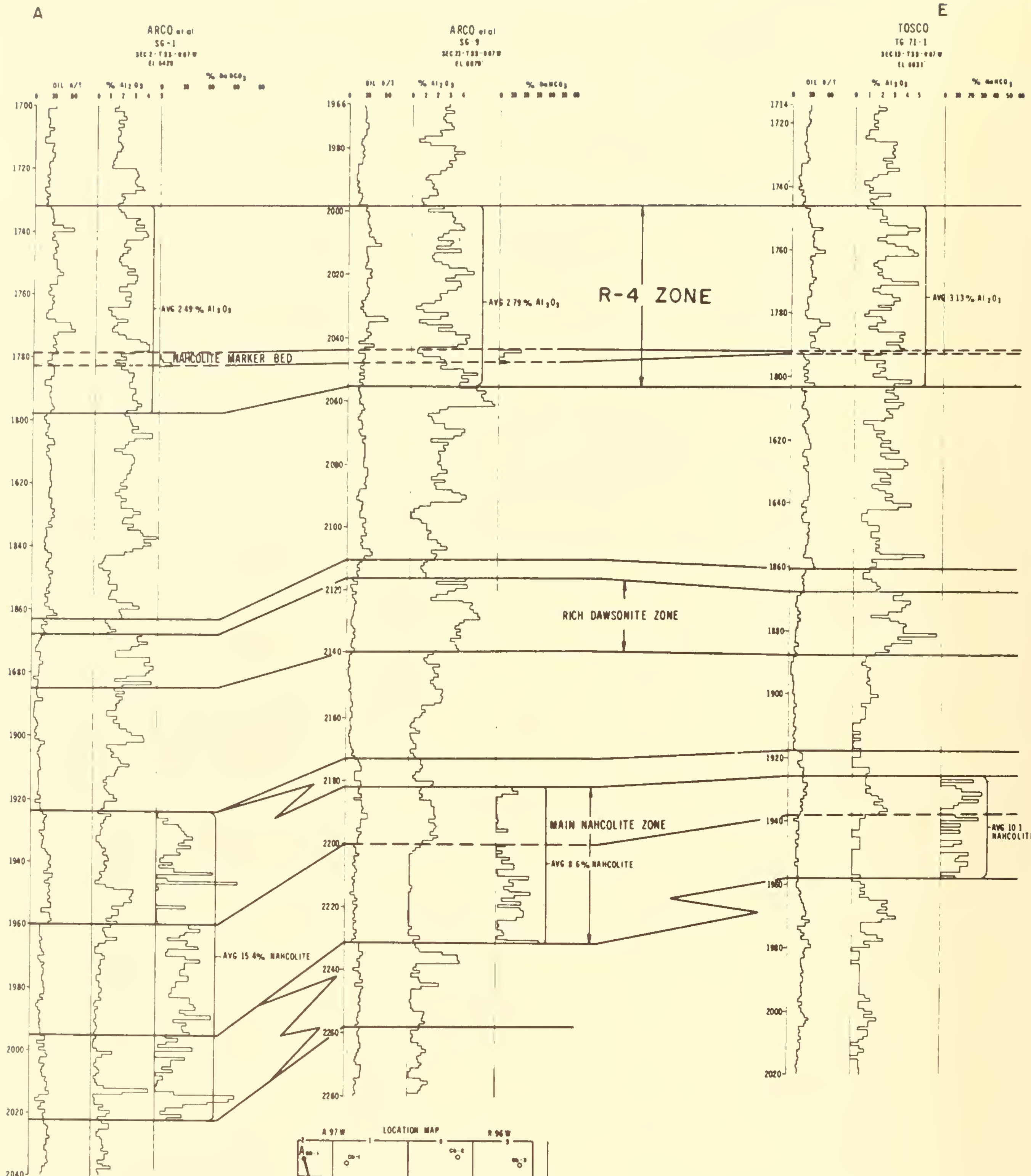
THE OIL SHALE CORPORATION

TG 71-1 COREHOLE
SEC. 13-T3S-R97W
RIO BLANCO COUNTY, COLORADO
T.D.-2530'
EL. 6851' G.L.

FIGURE 2-8

Table 2-1 POTENTIAL MINEABLE OIL SHALE RESOURCES TRACT C-b

SECTION	AVERAGE GRADE GPT	AVERAGE THICNKESS FEET	RESOURCE Bbls. x 10^6
Mahogany Mine Zone	36	77	940
R-4 Zone	30	55	582



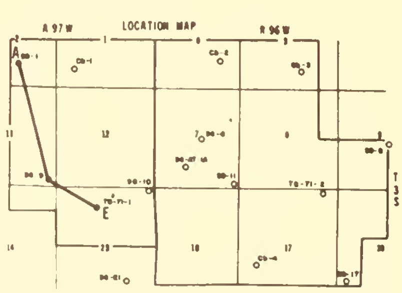


FIGURE 2-9

NORTH-SOUTH
STRATIGRAPHIC SECTION A-E
NAHCOLITE-DAWSONITE
(Al_2O_3) RESOURCES

Table 2-2 NAHCOLITE AND DAWSONITE RESOURCES
TRACT C-b

NAHCOLITE RESOURCES

Zone	Extent (Acres)	Average Grade(%)	Average Thickness(Feet)	Resource(Tons)
Main Nahcolite Zone	3460+	8 %	35±	30,000,000
DAWSONITE RESOURCE AS ALUMINA (Al_2O_3)				
R-4 Zone	5093	2.5 %	56	20,000,000
Rich Dawsonite	5093	3.5 %	20	12,000,000

Dawsonite, an alumina-bearing mineral, is found throughout the Mahogany zone, However, as the concentration of potentially recoverable alumina (Al_2O_3) in this part of the section averages less than 1 percent, dawsonite extraction is not economically feasible. Within the lower oil shale zone of the Parachute Creek section, there are numerous thin intervals (usually less than 10 feet thick) which average about 5 percent alumina. Figure 2-7 shows the vertical distribution of the richer alumina-bearing sections within a 300-foot interval in the "lower oil shale zone."

Because dawsonite might enhance the future economic potential of the R-4 zone beneath the Tract, special attention was given to the alumina content in this interval (Figure 2-10). In the R-4 zone, the alumina percentage ranges from a high of 3.13 percent in the TOSCO TG-71-1 to a low of 1.79 percent in the SG-17. The dawsonite resource of the R-4 zone (Table 2-2) contains about 20,000,000 tons of alumina, or about 4000 tons of alumina per acre.

Another alumina zone of interest occurs about 50 feet stratigraphically below the base of the R-4 zone (Figure 2-9). This rich dawsonite zone ranges from 17 to 23 feet thick on the Tract and averages about 3.5 percent alumina with a range from 2.70 to 3.91 percent. This zone has a rather uniform thickness across the basin, but increases in alumina content to the north and west of the Tract. As this alumina-rich zone occurs in a lean oil shale zone that averages approximately 10 GPT, it has no apparent economic potential. There are about 12,000,000 tons of alumina in this zone (Table 2-2).

Samples of the Parachute Creek member from four core holes have been analyzed to determine concentrations of antimony (Sb), arsenic (As), boron (B), cadmium (Cd), fluorine (F), mercury (Hg), and selenium (Se). Except for the concentrations of fluorine and arsenic,

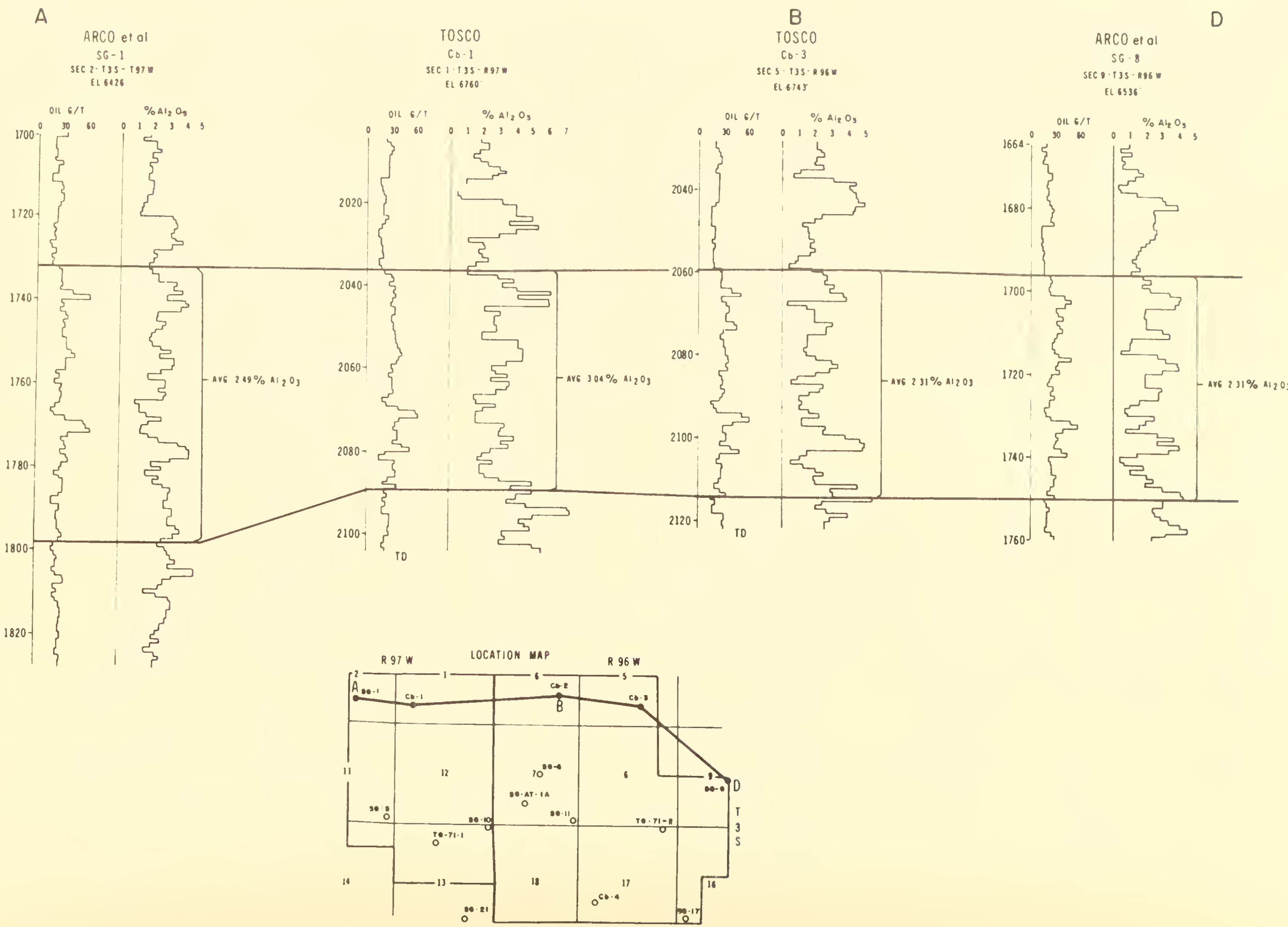


FIGURE 2-10

EAST-WEST STRATIGRAPHIC SECTION A-B-D
DAWSONITE (Al_2O_3) RESOURCES

which gradually increase with depth, no strong correlations between concentrations of elements and depth or stratigraphic zone are indicated. The range of concentrations of these base elements is as follows:

	Concentration (PPM)	
Element	Maximum	Minimum
Antimony	3.0	1.0
Arsenic	125.0	10.0
Boron	300.0	10.0
Cadmium	0.7	0.5
Fluorine	3400.0	600.0
Mercury	1.3	0.02
Selenium	10.0	2.0

The only two trace elements in the oil shale that also occur in significant amounts in the ground water are fluorine and boron. Fluorine may reach a concentration of 45 parts per million in highly saline water below the R-4 zone, but normally does not exceed 20 parts per million. Boron concentrations in ground water may be as high as 47 parts per million in saline water, but is usually less than three parts per million. None of the trace elements occur in significant amounts in the surface waters of the basin, except fluorine, which is present in low concentrations. Consequently, it can be assumed that, except as noted, these elements are not released in large amounts to the ground and surface water.

2.1.8 Geologic Hazards

Detailed surface geologic mapping of the Tract and vicinity was conducted to identify existing natural hazards such as landslides, rockfall areas, slump fractures, soil creep and mud flow areas. Minor soil creep and slump occurs near the heads of several tributaries along Willow Creek.

Areas of Quaternary deposits, which include floodplain alluvium, fan alluvium, colluvium, and mixed alluvium and colluvium, have the greatest potential for erosion. These areas are shown on Figure 2-6.

At present, erosion appears to be most severe at the heads of some of the smaller gulches. The alluvial material is locally incised 20 to 30 feet below the floors of the gulches, and the heads of the gulches exhibit slopes on the order of 45^0. Such conditions contribute to instability, not to mention the potential for problems if building occurs on subcompacted gravels and sands.

Significant flooding will generally be restricted to established stream floodplains, which are defined by the distribution of floodplain alluvium. Sheet flooding will essentially occur everywhere.

2.1.9 Summary

The Piceance Creek basin is an intriguing area from a geologic standpoint. Geomorphic processes operating on the sedimentary beds, uplifted and deformed by structural and erosional processes, have developed scenic areas around the periphery of the basin. Within the basin these same processes operating on the essentially flat-lying Tertiary sediments have produced a generally monotonous series of valleys and convex ridges radiating away from the east-west running main stream of Piceance Creek and south-north running Yellow Creek.

Upon closer inspection, one sees subtle variations in stream patterns and topography. The ubiquitous Uinta Formation superficially masks structures developed in older rocks. Specific site-related information can explain these patterns if they exist and can detail structure and stratigraphy. Specific site-related information is necessary to ascertain the economic potential. The results of site-specific investigations are more fully developed as they pertain to the baseline in other volumes of the Final Baseline Report.

2.2 Climatology

2.2.1 Introduction

The various features controlling the climate across northwestern Colorado are latitude, distance from oceans, location with respect to storm tracts, elevation, and shape and orientation of the topography. Of major importance in climate control is the blocking effect of the Sierra Nevadas in California and the Cascade Mountains in Washington and Oregon. The continental divide on the east is an effective barrier to air flow from the Gulf of Mexico and cold air flow from the northern plains. Thus, northwest Colorado is an area protected from most "traveling" weather disturbances by the major physiographic features.

The climate in northwest Colorado is generally classified as semi-arid and consists of four distinguishable seasons. Wide variations in precipitation, temperature, and wind movement from place to place result primarily from the varied topography. The local climate is strongly influenced by microclimatic features e.g., slope, aspect, elevation, soil type, and vegetation. In particular, surface wind patterns and vertical temperature profiles are almost entirely dependent upon the local topography.

Precipitation from late October to mid-April consists predominantly of snow, particularly at higher elevations. Accumulations occasionally exceed 100 inches and do not completely melt until late summer in the higher mountains. Winds are generally west-to-east but are greatly modified by local topography. Wind velocities average four to ten miles per hour.

2.2.2 General Climate of the Western United States

The bulk of the western half of the United States is covered by the Arid and Semi-arid climatic classifications of Köeppen. Only along the west coast does the climate ameliorate to the more moderate Cs (Mediterranean) and Cf (warm temperature) climates. The orographic effects of the coastal mountain systems and the main ridge of the Sierra Nevada Mountain Range and Cascade Mountains reduce the moisture content of any prevailing westerly winds so that the lee sides of these ranges are arid to semi-arid climates. This effect continues eastward even into the continental interior and is enhanced by the high elevations of the Rocky Mountains. Once the prevailing westerly winds cross the inter-mountain area of Nevada, Idaho, and Utah (the Basin and Range Physiographic Province), an area of steep narrow mountain ranges

and wide, flat basins, they meet an area of high average altitude. The western edge of this elevated area occurs in eastern Utah at the Wasatch Mountains.

This broad elevated area is the Colorado Plateau Province covering parts of eastern Utah, western Colorado, northeastern Arizona, and northwest New Mexico; it is flanked on the east by the middle Rocky Mountain and the southern Rocky Mountain Provinces. The effect of the plateau on the average elevations of some of the Rocky Mountain states is shown in Table 2-3.

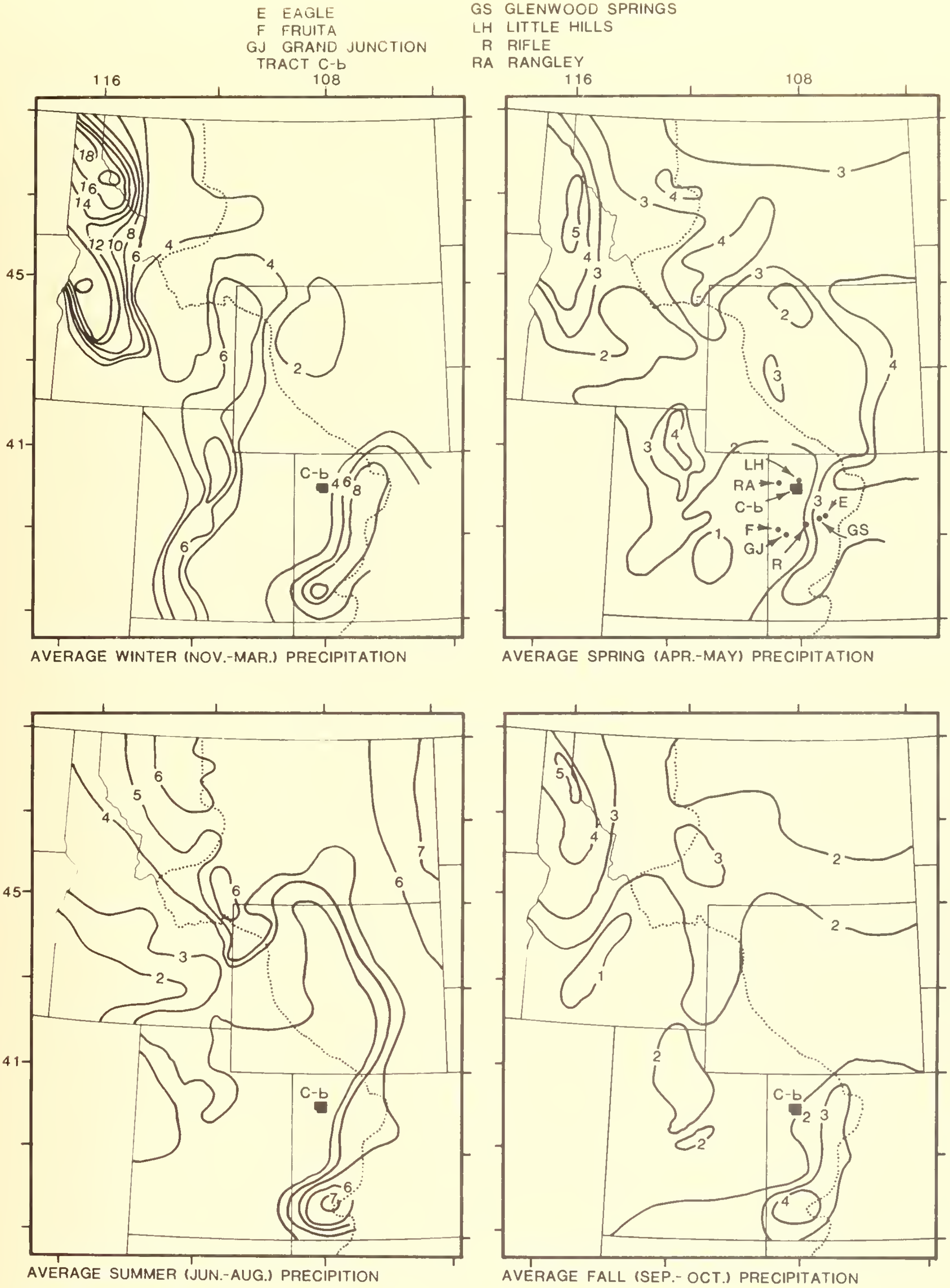
Table 2-3 HYPSOMETRIC DIVISION OF SELECTED STATES IN THE ROCKY MOUNTAIN WEST

State	Area (square miles)	Percent of State at an Elevation (in thousands of ft) between			
		1 and 2	2 and 5	5 and 10	>10
Colorado*	104,247	0	2.5	78.5	19
Eastern Idaho	83,557	0.5	43.5	54	2
Montana	147,138	2	73	24	1
Eastern Utah	84,916	0	31	66	3
Southern Wyoming	97,914	0	19	77	4
Entire Area	517,772	0.6	37	57	6
Percent of long-term Precipitation stations in elevation zones		2	51	47	0

*West of 106°W only.

Source: Bradley 1976

This table points out how much higher above sea level Colorado is compared to its neighbors. Almost 20 percent of Colorado west of 106° longitude lies above 10,000 feet; almost 80 percent lies between 5000 feet and 10,000 feet. This increase in elevation is reflected to a certain extent in the amount of precipitation received. The orographic effect, the forced lifting of air masses, of the elevated areas of the west can be seen in the distribution of seasonal precipitation (Figure 2-11) and can be seen in average total precipitation for selected areas of the states.



(SOURCE: BRADLEY 1976)

AVERAGE SEASONAL PRECIPITATION (INCHES)

FIGURE 2-11 1941-1970 PART OF ROCKY MOUNTAIN WEST

2.2.3 General Climate of the Plateau Province and Piceance Creek basin

The climate of the Plateau Province depends to a considerable degree on topography. High elevations result in comparatively cool summer temperatures, and winter temperatures may reach a very low minimum. The irregular topography means that local conditions have a marked influence on cold temperatures. The high Rocky Mountains to the east generally prevent the westward progress of cold continental polar air masses from the northern plains; hence, major cold waves with high winds, i.e. blizzards, are quite rare. During the summer intensive heating produces frequent afternoon thundershowers but total rainfall is generally light. Consistent with diminished precipitation the mean cloudiness is also diminished.

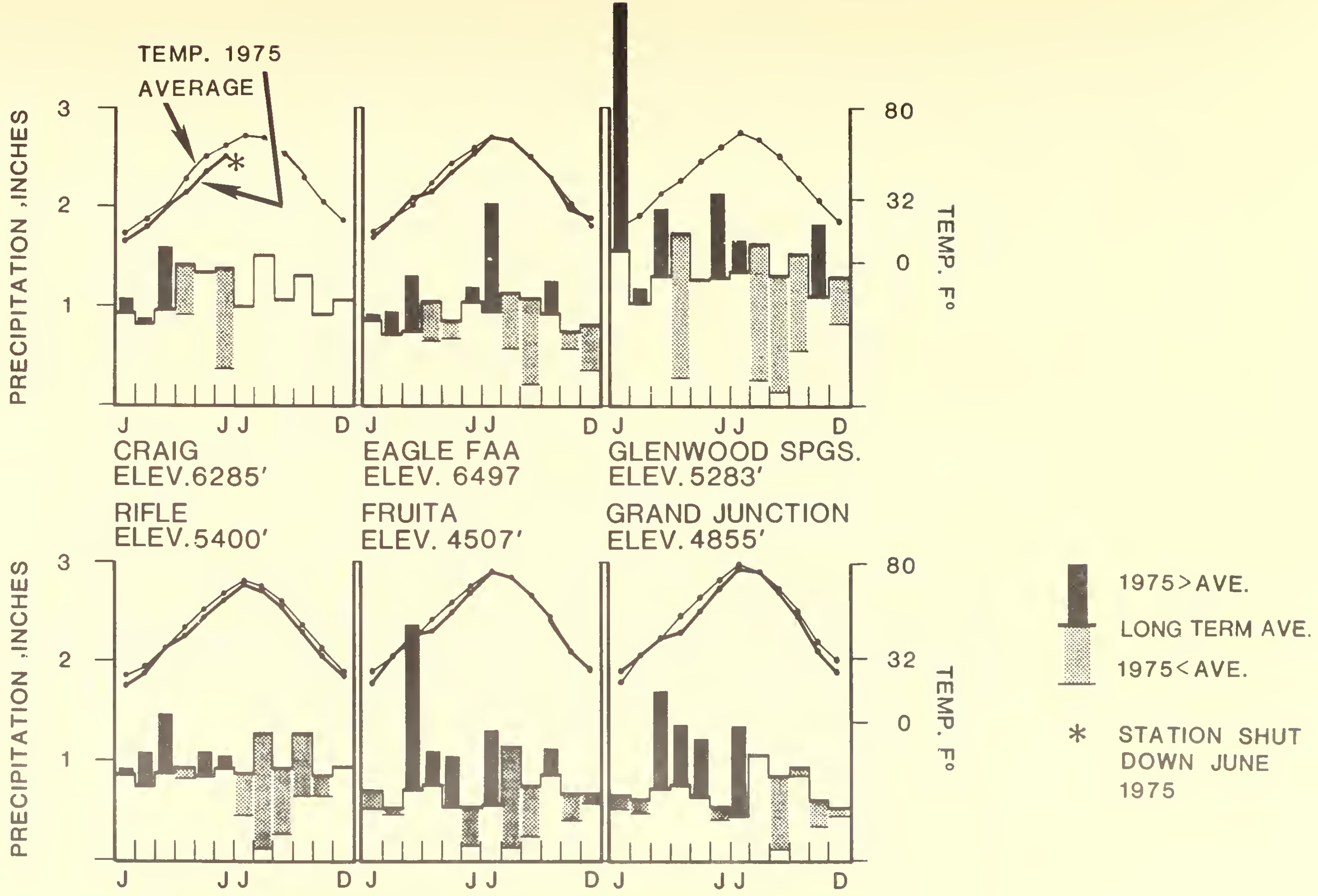
Because of the continental nature of the region, summer heating is very effective and causes higher daytime temperatures than at west coast stations. Clear skies allow nighttime cooling through radiation which contributes to the high diurnal temperature range; continentality and topographic effects increase the diurnal and yearly temperature range. Radiational cooling of modified massive polar air may cause fog in the valleys in the winter.

Pacific cyclones and marine polar air that reach the plateau region produce comparatively small amounts of precipitation. The air masses have been dessicated by the forced ascent over the various mountains to the west; thus the entire plateau region is in a rain shadow.

Nevertheless the increase in overall elevation of the plateau causes easterly moving air masses to rise sufficiently to increase the average precipitation on the Colorado portion of the Plateau (Figure 2-11). This effect of elevation is repeated even in local areas where more precipitation is received in the hills and elevated areas than in the valleys. Figures 2-12 and 2-13 show the histograms of selected weather stations in or near the study area. Figure 2-14 shows their location with respect to Tract C-b.

In spite of this increase in precipitation the climate of the Piceance Creek basin is usually classified as Arid-Steppe (BS Köeppen), although some stations, because of the low average temperatures, would calculate as a Df, cold snow forest climate. (See for example Little Hills, Craig, Glenwood Springs, Marvin Ranch, and Altenbern, Figures 2-12 and 2-13.) Characteristics of this climatic type are abundant sunshine, relatively warm summer temperatures, low relative humidity, and cool nights. In midwinter, although average temperatures may be quite low, the clear skies, high incidence of solar radiation, and dry air combine to provide a generally pleasant environment for outdoor activities. The clear skies and

SOURCE: DEPT. OF COMMERCE



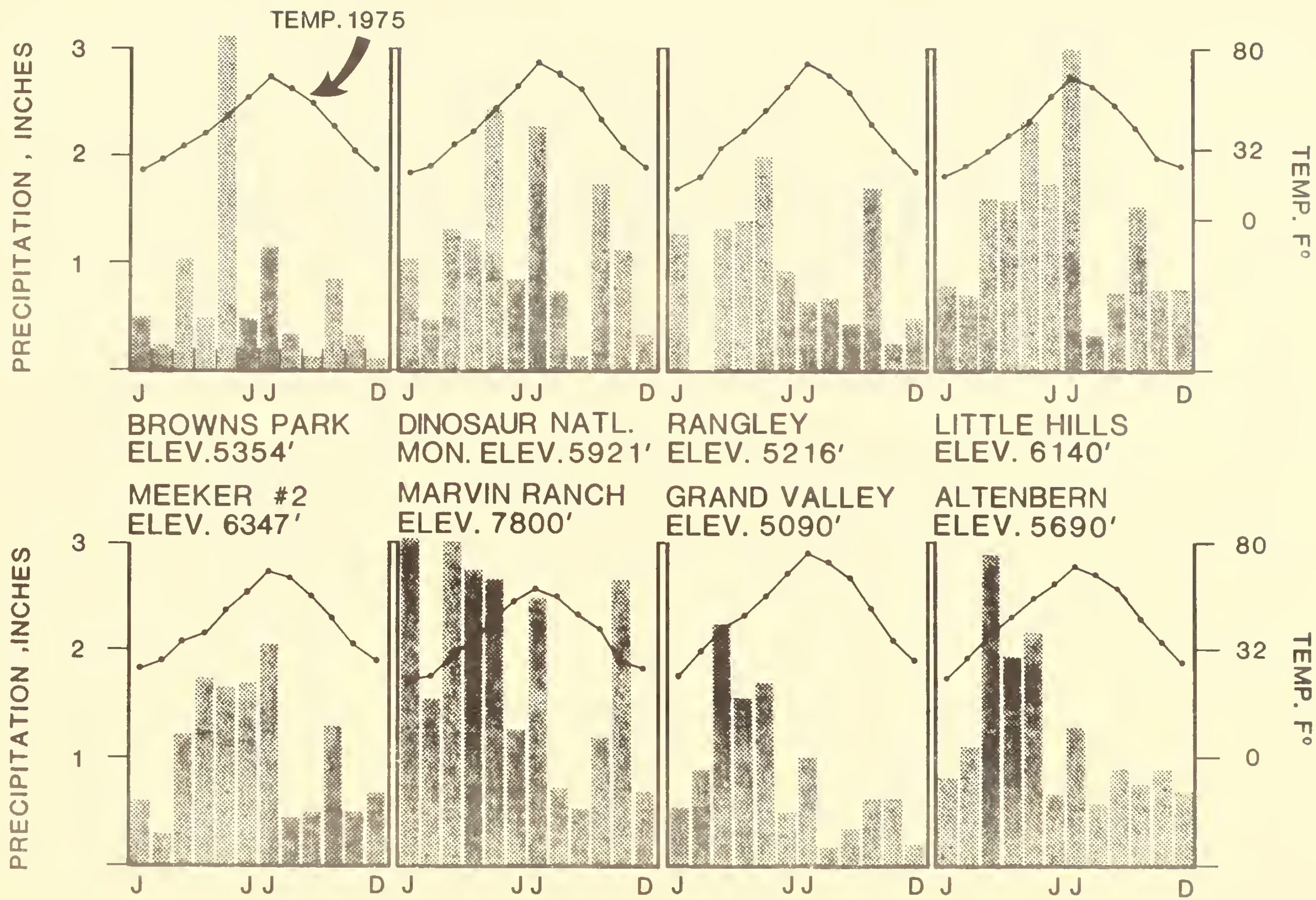
SELECTED CLIMATIC STATIONS NORTHWEST COLORADO

SHOWING MONTHLY PRECIPITATION AND TEMPERATURE

(LONG-TERM AVERAGE AND 1975)

FIGURE 2-12

SOURCE DEPT. OF COMMERCE

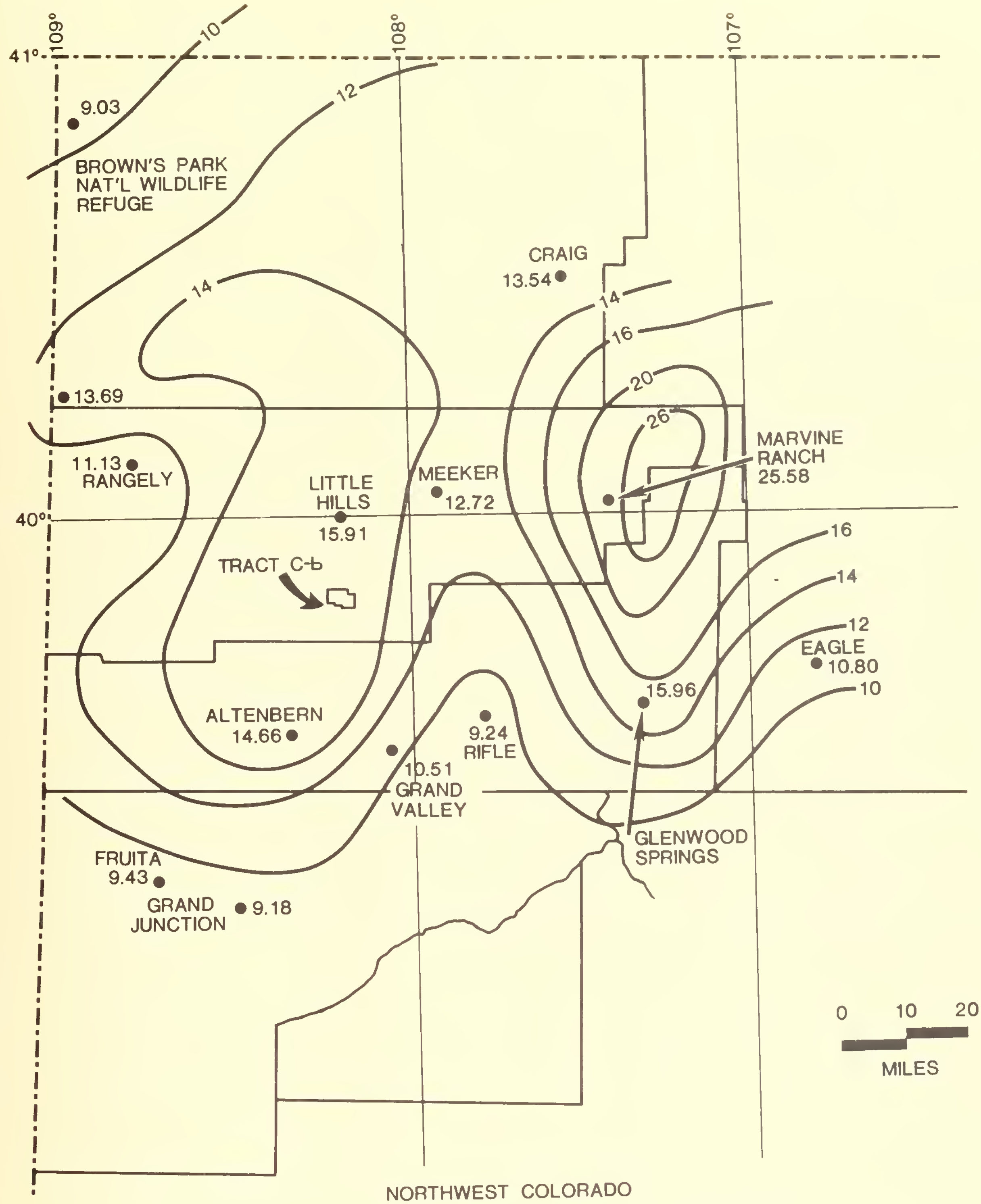


SELECTED CLIMATIC STATIONS NORTHWEST COLORADO

SHOWING MONTHLY PRECIPITATION AND

TEMPERATURE FOR 1975

FIGURE 2-13



NORTHWEST COLORADO

SHOWING LOCATION OF SELECTED CLIMATIC STATIONS

FIGURE 2-14 AND OIL SHALE TRACT C-b — ISOHYETAL INTERVAL 2 INCHES

dry air can be attributed to the influence of a high pressure cell and subsiding air aloft. Western Colorado is often dominated by a surface high pressure or a long wave ridge in the upper atmosphere. Either of these climatic phenomenon and subsiding air lead to clear skies and dry air with the resultant high incidence of solar radiation and low relative humidity. The clear skies allow excessive nighttime radiation loss with low nighttime temperatures. These conditions can also lead to small pressure gradients, light variable winds, and stagnating air.

Precipitation and temperature histograms for selected stations in northwest Colorado are shown in Figures 2-12 and 2-13. Average figures are shown for Craig, Eagle FAA, Glenwood Springs (precipitation only), Rifle, Fruita, and Grand Junction (Figure 2-12, Table 2-4). Long term averages at these stations show approximately equal distribution of precipitation throughout the year, i.e., small standard deviation. Comparing average yearly precipitation and temperature against values for 1975, it appears that total precipitation in 1975 approximated the average with temperatures somewhat lower, particularly in the spring. While precipitation in 1975 approximated the long term average, it is not equally distributed throughout the year. In general 1975 had a wet spring and early wet summer. A dry late summer was followed by a wet early fall (October) and a drier than average November and December. This dry period carried over into January 1976. While no tests have been made on the standard deviations of monthly means for the period of record, it appears that variability in monthly precipitation can be expected in the Piceance Basin with the attendant effects on the biologic realm. This variability is distributed such that over a period of years the average monthly precipitation for any one month approximates that for any other month (see Wymore 1974 and Marlatt and Reihl 1963). The drier stations, e.g., Fruita and Grand Junction, show greater variability from season to season. Variability in precipitation is of course a characteristic of semi-arid climates, and so the precipitation patterns are not surprising. The cooler than average spring temperatures in 1975 can be explained by the increased cloud cover that accompanied the increase in precipitation and thus contributed to the delay in warming.

The precipitation figures were broken down by season in the same manner chosen by Bradley (1976), that is, winter months are November through March; spring months are April and May; summer months are June, July, and August; and fall months are September and October. In this manner, additional patterns are seen to aid in classifying the precipitation regimes of the stations.

Two distinct patterns emerge, one for those stations in the Colorado River Valley and one for those stations in the Plateau and at higher elevations (Table 2-5). In the Colorado River Valley

TABLE 2-4 MONTHLY TEMPERATURE AND PRECIPITATION AT SELECTED STATIONS IN NORTHWEST COLORADO
RECORDS FOR 1975, 1976, AND LONG-TERM AVERAGE

Craig
6285 Elevation (Station shut down July 1975)

	1975		Ave (37 Yrs)	
	Temp	PPT	Temp	PPT
Jan	15.8	1.10	47.3	.92
Feb	20.3	.84	22.4	.83
Mar	30.7	1.60	29.7	.95
Apr	37.8	.92	42.1	1.40
May	48.3	1.36	57.5	1.36
Jun	56.7	.38	59.0	1.38
Jul	-	-	66.6	.97
Aug	-	-	64.7	1.51
Sep	-	-	56.1	1.09
Oct			45.4	1.32
Nov			31.8	.94
Dec			21.7	1.11
			Total	13.78
			Ave	1.15
			Std Dev	.23

Rifle
5400 Elevation

	1975		1976		Ave (55 Yrs)	
	Temp	PPT	Temp	PPT	Temp	PPT
Jan	18.2	.84	18.5	.50	23.2	.92
Feb	25.2	1.11	33.3	1.81	29.4	.76
Mar	36.9	1.46	21.7	1.81	37.3	.87
Apr	42.1	.80	46.5	.89	47.1	.93
May	51.4	1.08	54.9	1.58	56.0	.81
Jun	60.6	1.02			63.3	.92
Jul	69.7	.42			70.2	.85
Aug	66.0	.10	66.3	1.13	68.3	1.25
Sep	58.4	.25			60.0	.92
Oct	46.9	.61			49.5	1.24
Nov	32.4	.61			36.3	.85
Dec	24.3	.94			26.3	.92
					Total	11.24
					Ave	.94
					Std Dev	.15

Eagle FAA
6497 Elevation

	1975		1976		Ave (36 Yrs)	
	Temp	PPT	Temp	PPT	Temp	PPT
Jan	17.8	.84	18.0	.88	18.0	.88
Feb	22.5	.95	23.3	.69	23.3	.69
Mar	34.3	1.15	31.1	.77	31.1	.75
Apr	39.0	.62	41.9	1.02	41.9	1.02
May	47.9	.66	51.3	.83	51.3	.83
Jun	57.0	1.20	63.7	1.13	58.9	1.01
Jul	66.4	2.06			65.9	.94
Aug	62.3	.58			63.7	1.13
Sep	55.2	.21			55.6	1.06
Oct	43.7	1.25			44.8	.94
Nov	29.4	.58			30.9	.75
Dec	23.6	.35			20.3	.80
					Total	10.8
					Ave	.90
					Std Dev	.14

Fruita
4507 Elevation

	1975		1976		Ave (69 Yrs)	
	Temp	PPT	Temp	PPT	Temp	PPT
Jan	20.0	.52	24.4	.11	25.1	.68
Feb	33.2	.45	38.1	.83	32.6	.58
Mar	41.2	2.39	39.3	.95	40.4	.70
Apr	46.1	1.06	51.0	.10	50.6	.77
May	55.9	1.02	61.1	1.10	60.4	.54
Jun	65.0	.16			68.4	.56
Jul	75.7	1.29			75.1	.59
Aug	71.0	.14	72.5	.52	72.4	1.13
Sep	62.9	.22			63.8	.75
Oct	51.0	1.12			51.0	1.12
Nov	35.9	.40			35.9	.40
Dec	28.1	.66			28.1	.66
					Total	8.48
					Ave	.71
					Std Dev	.22

Glenwood Springs
5823 Elevation

	1975		1976		Ave (68 Yrs)	
	Temp	PPT	Temp	PPT	Temp	PPT
Jan	20.2	4.04	22.0	1.03	-	1.59
Feb	26.7	1.14	34.2	1.26	-	1.04
Mar	37.5	1.95	33.8	1.89	-	1.32
Apr	42.0	.24	46.4	.96		1.74
May	51.5	1.29	54.4	1.34		1.28
Jun	60.1	2.12				1.30
Jul	68.8	1.61				1.37
Aug	64.8	.26	64.7	1.35		1.62
Sep	57.0	.13				1.34
Oct	46.1	.57				1.52
Nov	32.2	1.80				1.12
Dec	24.2	.81				1.29
					Total	16.53
					Ave	1.38
					Std Dev	.20

Table 2-5 COMPARISONS OF 1975 PRECIPITATION BY SEASON WITH 1941-1970 AVERAGE

	Winter Nov-Mar	Spring Apr-May	Summer Jun-Aug	Fall Sep-Oct	Decreasing Order of PPT by Season	
Browns Parks	3.27≃	3.68>	2.04≃	1.04≃	Sp,W,S,F	Plateau Stations
Craig LTA	4.75≃	2.76≃	3.86≃	2.41≃	W,S,Sp,F	
	4.89≃	2.28≃	2.62<	1.98≃		
Dinosaur	3.35≃	3.67>	3.84>	1.89≃	S,Sp,W,F	
Rangely	2.90≃	3.41>	2.19≃	2.20>	Sp,W,S,F	
Little Hills	4.46>	3.91>	5.11>	2.27≃	S,W,Sp,F	
Meeker	4.10≃	3.40>	4.20>	1.78≃	S,W,Sp,F	
Marvin Ranch	12.41>	5.41>	4.45≃	1.77<	W,Sp,S,F	Mtn Station
Eagle LTA	3.87<	1.85<	3.08<	2.00<	W,S,F,Sp	Colorado River Stations
	3.81<	1.28<	3.84<	1.46<		
Glenwood Springs LTA	5.36≃	3.02≃	4.29≃	2.86≃	W,S,Sp,F	
	9.74>	1.53<	3.99≃	.70<	W,S	
Rifle LTA	4.32≃	1.74≃	3.02≃	2.16≃	W,S,F,Sp	
	5.32>	1.88≃	1.54<	.86<	W,Sp,S,F	
Grand Valley	5.30>	3.26>	2.71≃	1.00<	W,Sp,S,F	
Altenbern	6.54>	4.11†>	2.52≃	1.68≃	W,Sp,S,F	
Fruita LTA	3.13≃	1.31≃	2.28≃	1.59≃	W,S,F,Sp	
	4.65>	2.08>	1.59<	1.34≃	W,Sp,S,F	
Grand Junction LTA	3.16≃	1.42≃	2.06≃	1.77≃	W,S,F,Sp	
	4.26>	2.61>	1.91≃	1.01<	W,Sp,S,F	

LTA Long Term Average - at least 38 years
≃ 1975 ppt approximates 1941-1970 average
> 1975 ppt greater than 1941-1970 average
< 1975 ppt less than 1941-1970 average

maximum precipitation occurs in the winter months and minimum precipitation in the fall. On the Plateau the maximum is generally in the summer months followed in quantity by the winter months. Browns Park and Craig, outside of the Piceance Basin, have the greatest average precipitation during winter as does Marvin Ranch located at 7800' elevation in the White Mountain Plateau. The least amount of precipitation is received in the fall months regardless of location. The difference in precipitation pattern and amount of precipitation might be attributed to the differences in elevation between the Colorado River Valley and the Plateau.

These patterns (Table 2-4) can be compared with Figures 2-12 and 2-13 and the 1941-1970 average (Figure 2-11) which indicate that the Plateau and higher stations had generally wetter springs and summers in 1975 than the 1941-1970 average; while in the Colorado River Valley, stations had wetter winters and a tendency toward drier summers and falls than the 1941-1970 average. In this regard, it is interesting to note that Bradley (1976) concluded that the springs of 1941-1970 were wetter than the previous 30 years, and the summers of 1941-1970 were the most anomalously wet period for at least 110 years. Fall precipitation for the 1941-1970 period was generally less than the 1890's, 1910's, and 1920's. Thus one may conclude that precipitation on the Plateau was significantly higher in the spring and summer of 1975 and that in the Valley the fall of 1975 was significantly drier, except the 1930's, than anytime since 1890. Bradley attributes the post 1941 changes to a tendency toward more meridional circulation types. (As discussed later, meridional flow was dominant in March and June of 1975.)

2.2.4 Climatology and Meteorology of Tract C-b

While microclimatic and micrometeorological parameters are greatly influenced by terrain features, the climate of the Piceance Creek basin, and hence Tract C-b, is also influenced by the regional synoptic controls. Certainly the wind structure above the Tract depends heavily on the upper (500 mb) level flows. At 700 millibars (mb) at Grand Junction prevailing winds are from the southwest and west-southwest. Winds are from the north or northeast only 10-15 percent of the time (Figure 2-15). It is interesting to note that in August and September 1974 the limited data available indicated that the Salt Lake City, Utah, upper level wind flows were closer to upper level air flow patterns over the C-b Tract than those over Grand Junction. Generally, the upper winds are from the west although in some months they range through all sectors.

The upper level flow history of the C-b Tract over the past two years has been one of alternate periods of zonal flow (east-west) patterns and meridional flow (north-south) patterns with some sequence of split flow. Zonal flow promotes rapid variations of a rather weak nature in the meteorological conditions in a region.

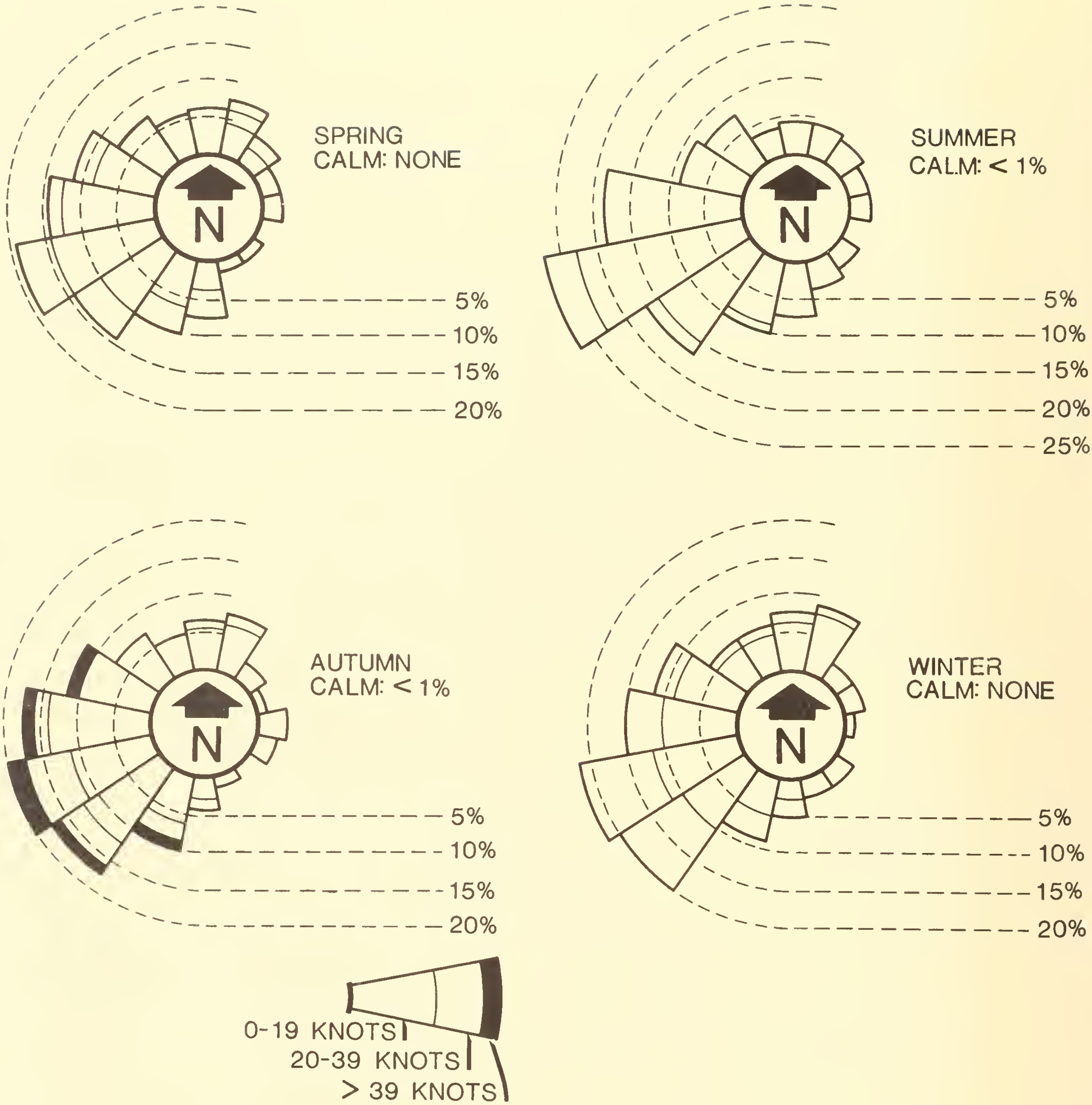


FIGURE 2-15 SEASONAL DISTRIBUTION OF WINDS AT 700 MILLIBARS, GRAND JUNCTION, COLORADO (ESSA, 1969)

Meridional flow causes rather extreme meteorological conditions (hot or cold depending on the relative location of the circulation pattern).

In general climatic extremes experienced on the Tract can be attributed to these flow patterns. For example, the unusually high number of extratropical cyclones experienced on the Tract in June 1975 was partly attributed to meridional flow. Similarly, in March 1975, meridional flow was more prevalent than in any preceding winter month during Tract operations and was the cause of numerous periods of cyclogenesis with a net result that temperatures in March were below normal and precipitation was above normal. An example of zonal flows occurred when, in September 1974, the eastward movement of a long wave and the weakening of a long wave ridge in western North America led to mild, fair weather and light winds on the Colorado Plateau.

The temperature structure above the Tract follows the dry adiabatic lapse rate above 1500 feet above the surface on clear days. On moist days, as one would expect, the temperature structure shows more of a wet adiabatic behavior. The lower 1500 feet show a more complex profile with evening inversions broken up by the mid-morning. Temperature inversions are more pronounced in the valleys.

Total precipitation patterns are influenced strongly by the local terrain and elevation differences. Average annual precipitation varies from less than 12 inches in the extreme northwest portion of the Basin to approximately 24 inches at higher locations in the southwest corner, making a precipitation lapse rate of five inches per thousand feet. Precipitation ±0.1 inch occurs on the average on 45 days per year, however, probably no more than 8 to 10 of these days have amounts totalling more than one-half inch.

Thunderstorms, often of short duration but of high intensity, may cause flash floods in the region during late summer. The fall season tends to be dry and mild, punctuated occasionally by an early fall snowstorm. Late spring snowstorms can occur up through late May.

Snowfall occurs on an average of 20 days and total cumulative amounts of 80 inches may reach in the Piceance Creek valley and more than 100 inches on the plateau top. Although snow depths may reach two feet in midwinter, at lower elevations there are only a limited number of days when the ground is entirely snow covered. At higher elevations, in wind drifted areas and areas protected from considerable direct solar radiation, snowpack depths of six feet or more may be expected.

Estimated annual consumptive use averages 26.5 inches at 5,000 feet decreasing to 11.5 inches at 8,000 feet, estimated by using the Blaney-Criddle methods, as discussed by Wymore (1972). The precipitation consumptive use ratio is 0.32 at the lower elevations and 2.2 at plateau top; or evaporative demand is nearly three times

precipitation in the valley and only half the amount of precipitation at the higher elevations. Even on top of the plateau, however, the lack of moisture-holding capacity in the soil and the high evaporative demand during the summer season limits significant timber stands to north-facing slopes, along stream gullies, and on protected hillsides.

The location of the Piceance Creek valley with respect to major sources of moisture, the low annual precipitation, the lack of moisture in the soil, and the low density of actively transpiring vegetation would indicate a low relative humidity and infrequent periods of fog and dew. Relative humidity averages range from 30-40 percent in summer to 75 percent in midwinter, with the average annual humidity being generally higher in the valley than on the plateau. Fog occurrences are restricted to a few days during winter and can be classified as radiational fog.

As is typical of midlatitude, mountainous, steppe climates, the air temperatures across the Piceance Basin are strongly influenced by the local terrain and air flow patterns. During spring, summer, and autumn air temperatures are generally moderate, and even in mid-winter, afternoon maximums are usually in the mid 40's (F^o). However, as a result of cold air drainage and stagnation, midwinter minimum temperatures are occasionally extremely low. (Frost is more common in valleys than on mesa tops because of air stagnation.)

With occasional summertime maximums over 100^oF, the annual range of temperature will exceed 150^oF. The number of frost free days varies from 50 days in the higher elevations above 8000 feet to 125 days in the lower elevations under 5,500 feet. The dry climate and short growing season have a limiting effect on the total biomass productivity of the Basin.

Topography of the Piceance Creek basin and surrounding regions strongly influences the wind patterns and the dynamics which govern the transport and diffusion of air contaminants. In the free atmosphere above 9,000 feet msl, the prevailing winds are from the southwest and west-southwest throughout the year. Near the surface, both velocities and direction are strongly dependent upon terrain characteristics and the local thermal environment. Diurnal variation in surface temperature patterns in the Piceance Creek valley and local topographic constraints combine to produce well developed valley wind regimes. Wind velocities are generally lowest about dawn and are greatest in the early afternoon, when, owing to the heating of the slopes by the sun, vertical mixing is most pronounced. During fair, warm afternoons the heated air moves up the valley (anabatic flow). At night, air cooled by outgoing terrestrial radiation along the higher ridges and mountain tops drains into the valley (downslope or katabatic flow). There is minimal air movement in the pooled cold air in the valley bottom; thus the wind direction will be controlled by local downslope drainage from the side canyons leading into the valley. The Piceance

valley temperature inversions formed by the cold air drainage are usually dissipated by surface heating during the day. During winter, however, snow cover reduces the surface heating and enhances the persistence of the temperature inversions and downslope flow patterns. Observed winds are stronger where the directions of the local surface winds and gradient flow are aligned.

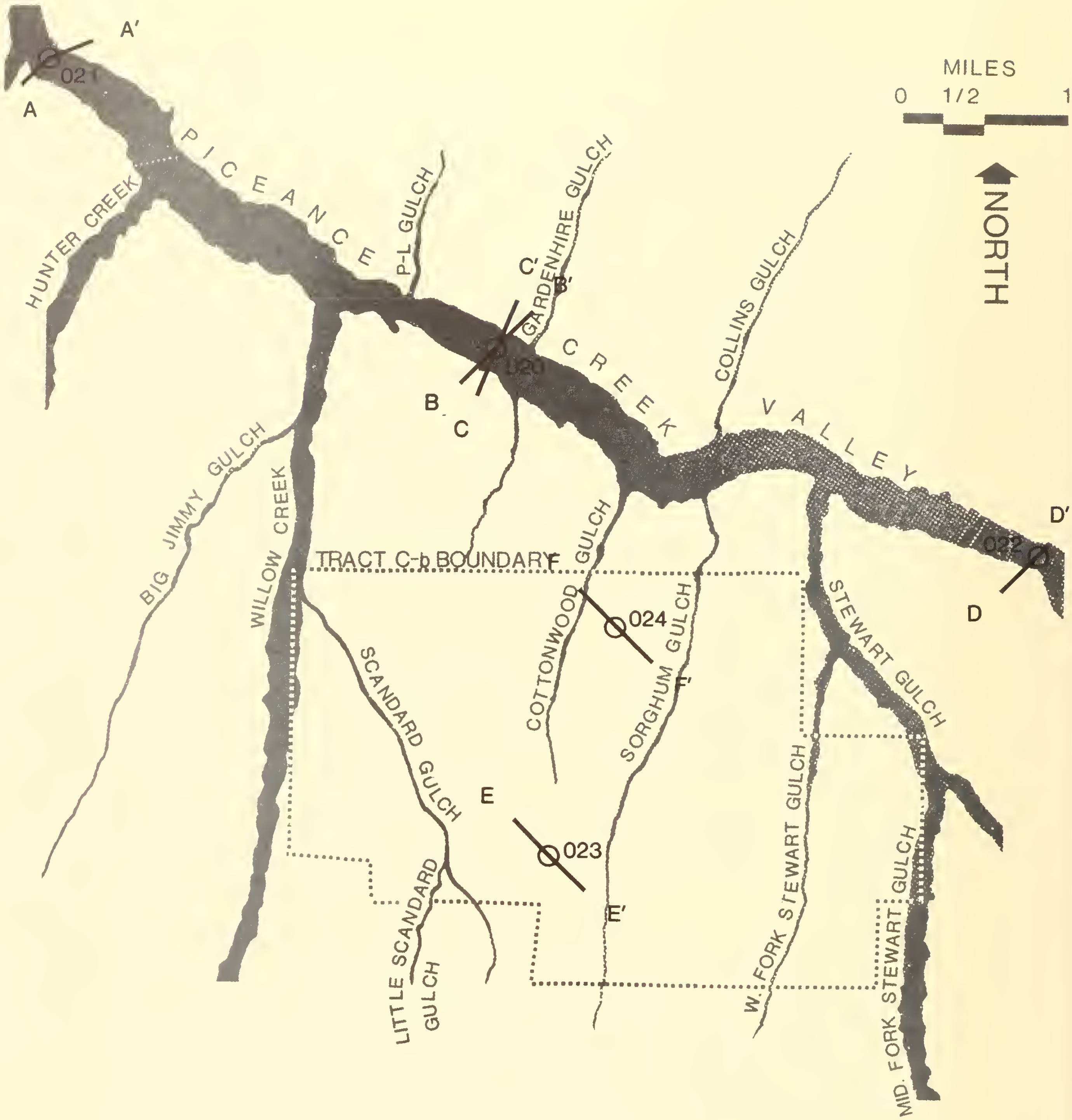
2.2.5 Micrometeorology of Tract C-b

The Piceance Creek basin is subject to local circulations (anabatic and katabatic winds) of varying intensities throughout the year. These flows are heat developed when clear skies and a weak pressure gradient--conditions which are rather common over western Colorado as discussed previously--prevail over the area. The conditions for katabatic winds occur during the night when the higher elevations cool more rapidly than the valley floor causing cold, dense air to collect and flow toward lower elevations. During the day the opposite effect occurs in that the high elevations receive more direct insolation earlier in the day, causing them to warm more rapidly. The resulting density difference between the valley tops and valley floor causes an anabatic flow with winds blowing up the valley floor and walls.

The topography of the C-b Oil Shale Tract is such that many microscale meteorological phenomena affect the region where the ambient air monitoring units are located (Figure 2-16). In particular, the three units in the Piceance Creek valley (Trailers 020, 021, and 022) are heavily influenced by a katabatic-anabatic flow regime. Trailer 023 and its associated 200-foot meteorological tower are located atop a plateau to the south of the valley, high enough to also be affected by gradient flow conditions. Trailer 024, located halfway between the valley and the meteorological tower, is affected by a mixture of the gradient and mountain-valley flow regimes.

In the Piceance Creek basin the valley-mountain flow regime is evident at the three monitoring trailers located in this valley. Of the three trailers, Trailer 022 has the most eastern location and the highest elevation above mean sea level. Trailer 021 is located at the western end of the valley and has the lowest elevation above mean sea level. Trailer 020 is intermediate in both location and elevation. These location and elevation differences cause micrometeorological effects to appear in the data as a result of the dominant anabatic-katabatic flow regime in the valley.

Elevations in the monitoring network range from about 6150 feet above sea level at Trailer 021 (near the Rock Creek School in the valley at the westernmost end of the monitoring network) to 6980 feet at the meteorological tower site (Trailer 023) atop the plateau within the Tract C-b. The largest gradients in elevation in



LOCATION OF AIR MONITORING TRAILERS

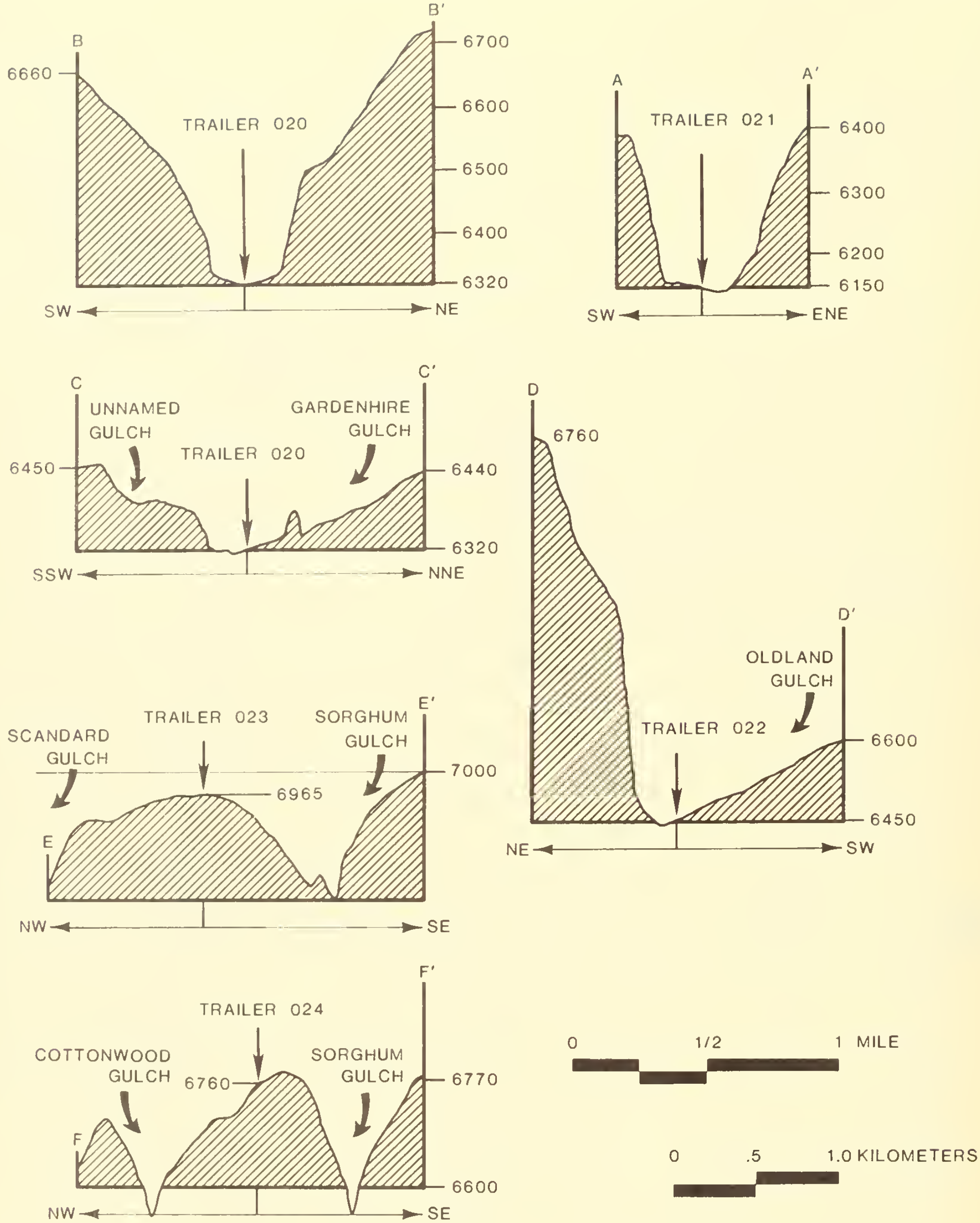
FIGURE 2-16

this area, occur at the Piceance Creek valley walls (Figure 2-17). However, the northern valley walls are slightly steeper than those at the southern boundary of the valley, which then slopes gradually upward toward the C-b Tract. The Piceance Creek valley decreases in elevation from east to west, so that nighttime katabatic cold-air drainage flows advect from east to west, or from Trailer 022, to Trailer 020, to Trailer 021.

As mentioned at the outset of this discussion, the terrain will have a large influence on the meteorology of this region. Considering first Trailer 022 at the eastern end of the monitoring network (Figure 2-17 Cross Section D-D'), a nighttime katabatic (valley or downslope) flow will exert a tremendous influence on this site. Of the three monitoring locations in the Piceance Creek valley, the valley wall is steepest and the relief is greatest at this site, thus, the nighttime katabatic flow is strongest here. That is, the downslope winds are constrained or channeled at this point such that the nighttime drainage winds often reach 15 miles per hour. In addition, the channeling effects of the Piceance Creek valley walls normally cause surface winds to flow from one of two preferred directions. At night the downslope winds parallel the valley contours, generally coming from 115° (east-southeast, referenced to true north). During the afternoon, or whenever suitable pressure gradient conditions exist, the winds generally come from the west-northwest because of the boundary conditions and channeling caused by the valley. This monitoring location has an elevation of approximately 6450 feet above sea level and is at the mouth of Oldland Gulch.

Trailer 020, midway down the Piceance Creek valley near the Redd Ranch at the mouth of Gardenhire Gulch, has an elevation of about 6320 feet above sea level. The valley walls are steeper to the north of this monitoring location (Figure 2-17 Cross Section B-B', C-C'). The Piceance Creek valley widens a little from Trailer 022 to Trailer 020 so that channeling effects are not quite as great at this location. Nevertheless, a well-developed katabatic-anabatic flow cycle affects this site, with the afternoon anabatic flow being well-developed. The channeling effects of the valley walls cause two preferred surface wind directions, southeast and northwest. However, other wind directions are experienced, particularly during the transition periods between downslope and upslope flows and during periods when the surface pressure gradient dictates to a large degree the surface wind direction. This might be one effect of the proximity of Gardenhire Gulch.

Trailer 021, located near the Rock Creek School, has the lowest elevation of the three valley trailers, 6150 feet (Figure 2-17 Cross Section A-A'). At this point, the Piceance Creek valley widens considerably toward the east, so that nighttime katabatic winds are rather light as are daytime anabatic winds. However, northwesterly surface winds caused by pressure gradient forces are occasionally moderate in force because of the slight channeling effects of the valley walls to the north and northwest.



CROSS SECTIONS

THROUGH AIR TRAILERS LOCATIONS

FIGURE 2-17 TRACT C-b

Site 023, where the 200-foot meteorological tower is located, is atop the plateau at an elevation of about 6980 feet above sea level (Figure 2-17 Cross Section E-E'), approximately 2.5 miles south of the Piceance Creek valley. This location is relatively high compared to its surroundings, with the nearest points having elevations greater than 7000 feet being five tenths mile to the south of the tower. The tower itself is on the top of the small knoll located between Scandard and Sorghum Gulches. Because of its location and the irregularities of the surrounding terrain, meteorological patterns are varied.

Wind instrumentation is mounted at four levels on the meteorological tower: 8 feet, 30 feet, 100 feet, and 200 feet. The top level of the tower is sometimes contained in gradient wind flow. That is, the winds at that level are sometimes generated by synoptic-scale features and are separated from terrain features and micrometeorological circulations. Occasionally, a weak anabatic flow influence is experienced. However, such is usually not the case with the three lowest measurement levels. To varying degrees, these levels are influenced by both the katabatic and anabatic circulation cells. When strong pressure gradient forces do exist in the region and the synoptic-scale wind flow is strong, all four tower levels will reflect a gradient wind flow with the winds increasing in strength with increasing height.

Trailer 024 is between the Piceance Creek valley and the meteorological tower location, about 1 mile south of the valley itself. The elevation of this site is approximately 6760 feet (Figure 2-17 Cross Section F-F'). The terrain slopes downward to the west, north, and east, and slopes upward toward the south, in the direction of the meteorological tower. This site is in a transition zone between the micrometeorological effects which prevail in the valley and those meteorological phenomena affecting the tower site. As a result, the meteorological parameters measured at this location are subject to rather rapid variations. The area is generally affected by a weak katabatic (downslope) flow at night and a weak anabatic (upslope) flow during the afternoon hours. Both gradient wind flows and terrain-induced wind flows affect the flow patterns at this location with the latter dominating.

These winds have a profound influence on the temperatures experienced in all three locations. Trailer 022 has the highest mean temperatures. It is warmest at night because radiational cooling is inhibited by the relatively strong winds. Conversely, Trailer 021 has the lowest mean temperatures. This is because nighttime winds are weaker at this location, allowing excellent radiational cooling and formation of strong inversions. Also, cool air from the eastern portions of the Piceance Creek valley drains into this area and settles, causing colder nighttime readings. Moreover, daytime high temperatures are highest at Trailer 022 and lowest at Trailer 021. Temperatures in the valley during September generally averaged

53.5°F, with an average maximum temperature of 71°F and an average minimum of 37°F. The highest maximum temperature for September was 93°F at Trailer 020 on the 9th and the minimum was 14°F for the 30th at Trailer 021.

During clear nights, with rather light pressure gradient-induced winds, rapid radiational cooling will occur in the region because of the barren nature of the terrain and the generally dry character of the air in this portion of the country. As a result, the diurnal range of temperatures will be extremely large. Because of the katabatic flow in the valley, nighttime temperatures will generally be lower in the valley than on the plateau. During the winter, temperatures in the valley may be 20°F lower than they are on the plateau in the early morning hours. In particular, the drainage effects will be spectacular at Trailer 021, which will often experience temperatures 10°F cooler than those at the other valley monitoring locations during the early morning hours. This phenomenon results from the pooling of cold air in the area of Trailer 021 because of its relatively low elevation and the light nature of the evening winds which inhibits surface mixing and promotes the strengthening of the nighttime ground-based inversion. During periods of strong gradient winds and/or cloudy skies, greater mixing of the air near the surface occurs and meteorological conditions (particularly temperature and humidity) are more uniform throughout the monitoring network (on the plateau and in the valley).

2.2.6 Summary

The C-b Tract is located in the Piceance Creek basin part of the semi-arid Plateau Province of western Colorado. Precipitation -- on the average less than 14 inches per year -- increases with altitude. Minimal cloud cover and an average elevation of over 6000 feet contribute to a high solar radiation gain during the daytime and an excessive amount of reradiation at night. The combination of high heat gains and losses along with the elevation and the continentality of the area, contribute to a large diurnal and yearly temperature range.

Recent precipitation records on Tract C-b compared with averages through the middle part of this century indicate that 1975 was wetter in the spring and early summer and drier in late summer and fall than the period 1941-1970.

Microclimatic features affect the local precipitation and temperature regimes with the basin and within the Tract. Anomalous data at the recording stations on the Tract can be attributed to terrain features. Data obtained at the various recording stations are characteristic of the local site only and interpretations should be made cautiously.

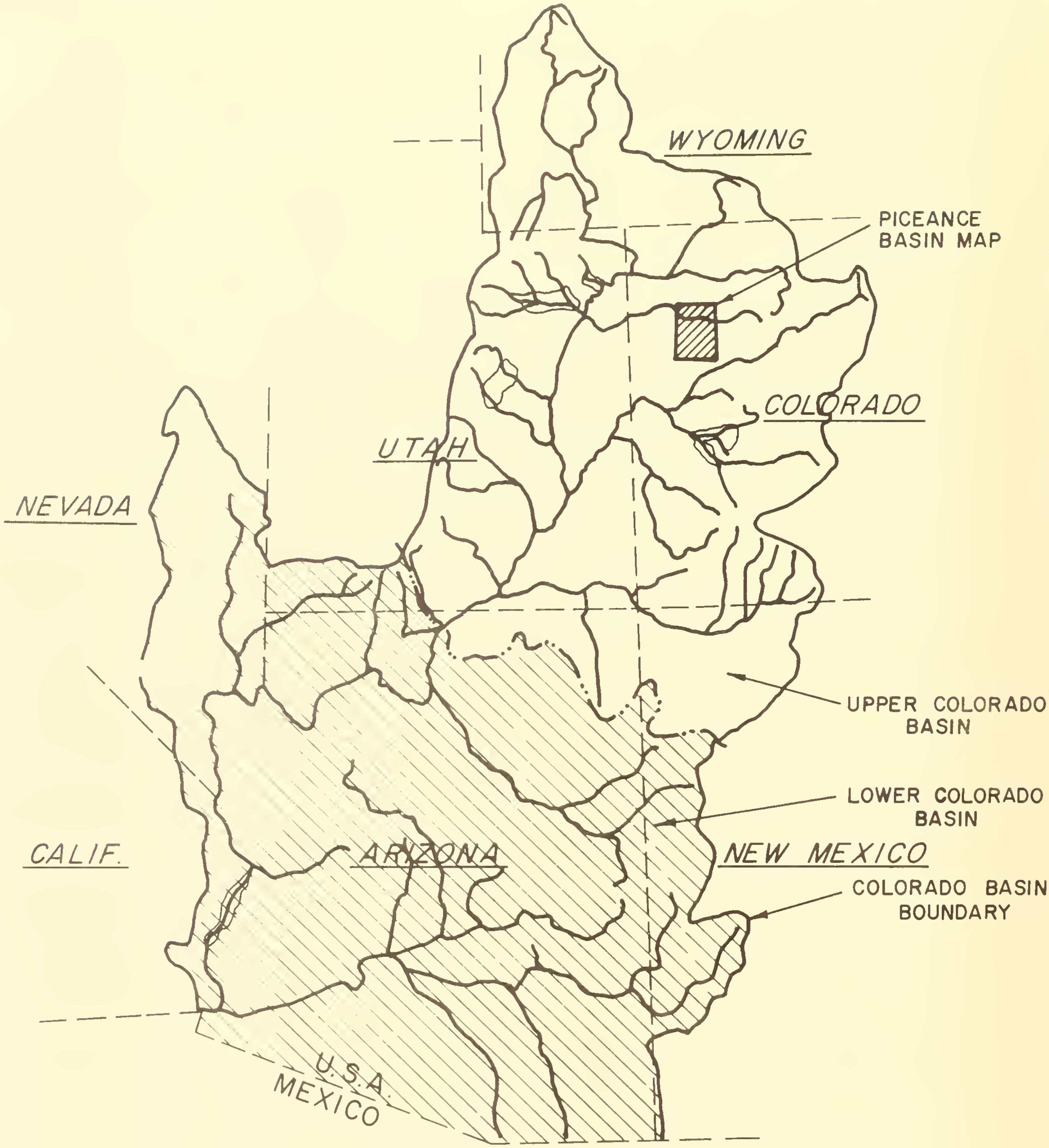
2.3 Hydrology

2.3.1 Introduction

The Piceance Creek drainage basin, and more specifically, the C-b Tract, are located in the Upper Colorado River basin (Figure 2-18). The Upper Colorado includes the watersheds between Lee's Ferry, Arizona, and the Great Divide in south-central Wyoming, approximately 109,580 square miles; this includes the subregions of the Green River, San Juan River, and upper main stem of the Colorado River. The watershed in which the C-b Tract is located is tributary to the Green River via the White River. The White River is one of two main drainages of northwest Colorado, north of the Roan Plateau.

Drainages on the Tract are tributaries to Piceance Creek, which flows into the White River 17 miles west of Meeker, Colorado. The White River flows into the Green River at Ouray, Utah; the Green River flows into the Colorado River southwest of Moab, Utah. Average annual flow of the Green River measured at Green River, Utah, is 4,187,000 acre-feet (5163 cubic hectometers) and averages 456 mg/l total dissolved solids (TDS). Average annual flow of the White River near Watson, Utah is 554,500 acre-feet (684 cubic hectometers) with an average of 439 mg/l TDS. The average flow in Piceance Creek at White River is 17,042 acre feet (21 cubic hectometers) with an average of 1827 mg/l TDS. Figure 2-19 presents average flow and average dissolved solids for selected gauging stations on Piceance Creek. While in general the salinity of the river increases from its headwaters to its mouth, there are streams such as Piceance Creek, in the upper reaches of the basin, that contribute salts far in excess of the average. Piceance Creek, as it enters the White River, contains an average of approximately 1800 mg/l TDS with an average annual flow of 17,043 acre-feet.

The water supply in the upper Colorado Basin originates mostly as winter precipitation in the mountains. Yearly stream flow peaks coincide with the spring snowmelt; summer precipitation is mostly limited to thunderstorms; except for the mountains, the area has a semi-arid climate. The bulk of precipitation is received in the cooler months, and in the higher elevations there is sufficient water for aquifer recharge in the mountains. The relationship bewteen surface water and ground water is such that once snowmelt in the mountains is gone, the local streams at lower elevations owe their base flow to inflow from seeps and springs.



COLORADO RIVER BASIN

FIGURE 2-18

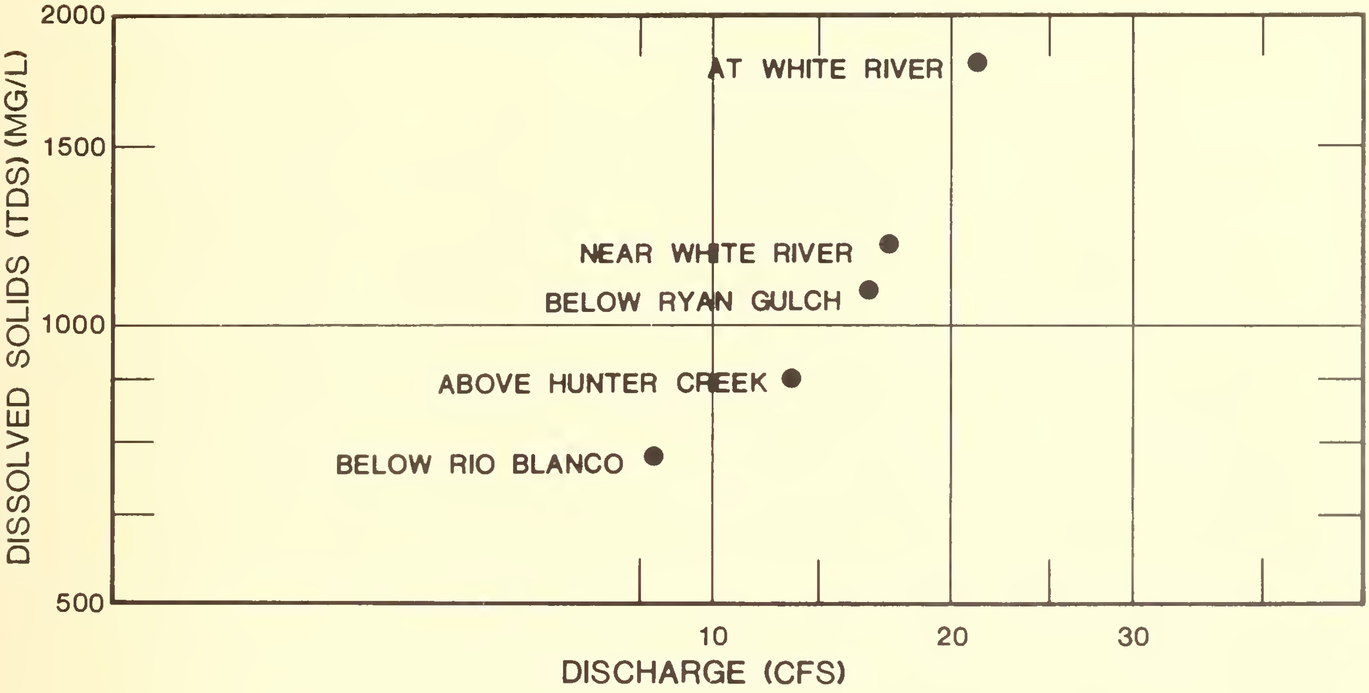


FIGURE 2-19

AVERAGE TDS VS AVERAGE DISCHARGE

SELECTED STATIONS ON

PICEANCE CREEK

A water balance is a means of approximating, in an accounting manner, the various factors of inflow, outflow, and stage involved in the hydrologic cycle. Such factors include precipitation, irrigation use, evapotranspiration, percolation, run-off, and change in storage. For all practical purposes, the available data indicate that storage changes in the Piceance Creek basin approach zero over the time span of the available record. Deep percolation and irrigation impacts could be thought of as small and averaging out with time. Quantitative data, although limited, are available and estimated ground water discharge from the basin is 26,100 acre-feet (32.2 hm^3).

2.3.2 Surface Waters

2.3.2.1 Surface Geology and Drainage

The Uinta Formation, as described in the section on Geology, forms the surface rock over most of the Piceance Creek drainage basin. Drainage areas and many areas on sideslopes and uplands are mantled with alluvium, colluvium, and deposits of mixed alluvial-colluvial origin. These deposits are derived largely from the siltstones and sandstones of the Uinta Formation.

The Piceance Creek drainage basin is not coincident with the Piceance Creek structural basin (commonly referred to as Piceance Basin). The Grand Plateau, on which the Piceance Creek formed, was downwarped in early Tertiary time. Hindrance of the drainage by the incipient structural depressions led to the formation of Lake Uinta. Deposition of the extensive oil shale deposits of the Green River Formation and the siltstones and sandstones of the overlying Uinta Formation followed not only in the Piceance Creek basin but also to the north in the Sand Wash basin and Green River basin of Wyoming, to the west in the Uinta Basin of Utah, and quite possibly to the south in a basin that has since been removed by erosion. Late Tertiary structural deformation and uplift ended deposition and created a subaerial, degrading environment, with the major drainage forming generally along the major structural axis of the basin. The southern edges, less affected by the local tectonic activity, remained generally stable so that a topographic divide developed between the emerging tributaries of the infant Piceance Creek and the more aggressive tributaries of the adjacent Colorado River.

Piceance Creek is a tributary to the Colorado River via the White River and Green River. The mainstem of the Colorado River, draining the south end of the Roan Plateau, has a shorter total length than its tributaries and thus is more aggressive in its erosive power. This active erosion on the obverse slope of the slightly upturned beds of the Roan plateau accounts for the development of the distinctive Roan Cliffs and the short but aggressive tributaries, dendritic in pattern.

The tributaries to Piceance Creek, draining the northern part of the Roan Plateau and coursing generally down the dip slope, are longer, less steep, and subparallel in their upper reaches. The major branches, e.g., Piceance Creek and Dry Creek, established their channels coincident with the major synclinal axes of the basin (Figure 2-1).

The tributaries are almost perpendicular to the direction of the course of Piceance Creek and hence perpendicular to the strike of the Hunter Creek syncline. Fracture and joint systems are numerous in the basin. The natural tendency for development of primary fracture systems is parallel to subparallel with the axis of the major structure or structures and also at a direction perpendicular to the main trend. Because of the numerous fracture systems and their natural tendency of formation, it has been suggested that the tributaries have developed along these fracture systems (Weeks 1974). This may be, but it should be remembered that these tributaries could be merely consequent streams developing along the dip slope of the south monoclinal limb of the Hunter Creek syncline.

Piceance Creek originates in the vicinity of the Grand Hogback, north of Rifle, Colorado, and flows west and northwest to the White River. It follows the southern edge of the Piceance Creek anticline as it traverses the oil shale areas. Yellow Creek is the other major drainage in the basin. Its course bends around the southeasterly plunge of the Rangely anticlinal trend; this drainage system would not be affected by Tract C-b operations. A more detailed discussion of the drainage patterns and hence geomorphology can be found in the section on Physiography.

2.3.2.2 Surface Water Flow

The United States Geological Survey (USGS) has maintained five stream flow gauging stations on Piceance Creek for varying periods. Figure 2-20 shows the locations of these stations. The runoff characteristics of the Piceance Creek basin are described primarily on the basis of the two longest gauging station records, Piceance Creek below Ryan Gulch (Figure 2-20, 09306200) and Piceance Creek at the White River (Figure 2-20, 09306222). The latter station is located at the mouth of Piceance Creek and reflects the total discharge from the basin. The gauge below Ryan Gulch, which has the longest record in the basin (since 1965), measures a major part of the runoff. Its record runs concurrently with the Piceance Creek gauge at the White River. Yearly discharge for these stations; for two White River stations; and for Roan Creek, a station on the Colorado River drainage, are shown in Table 2-6.

In comparing average discharges by month for the five stations (Figure 2-21) with the discharge for 1975, one sees that discharge during 1975 in the Piceance Creek watershed was higher than average.

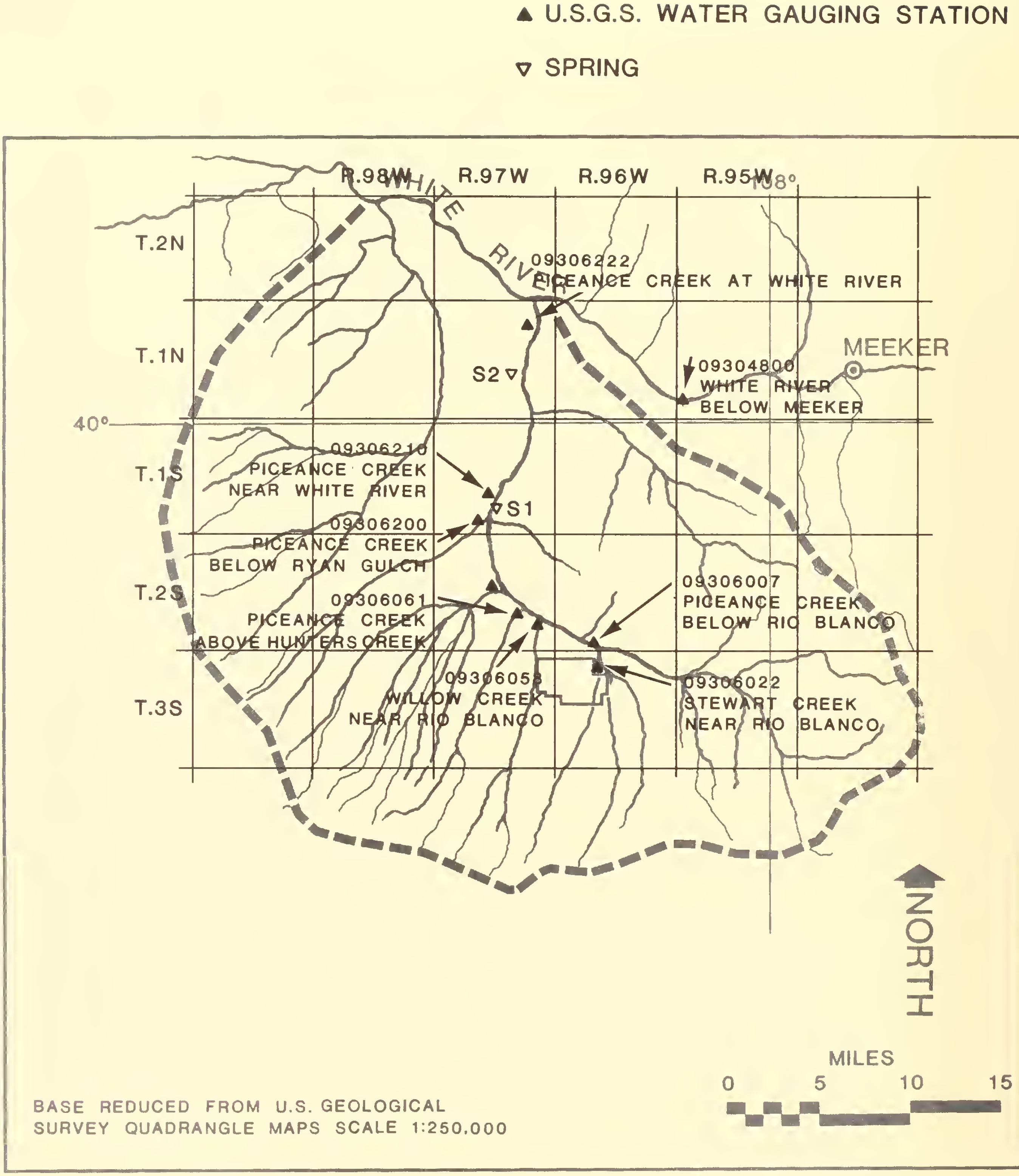


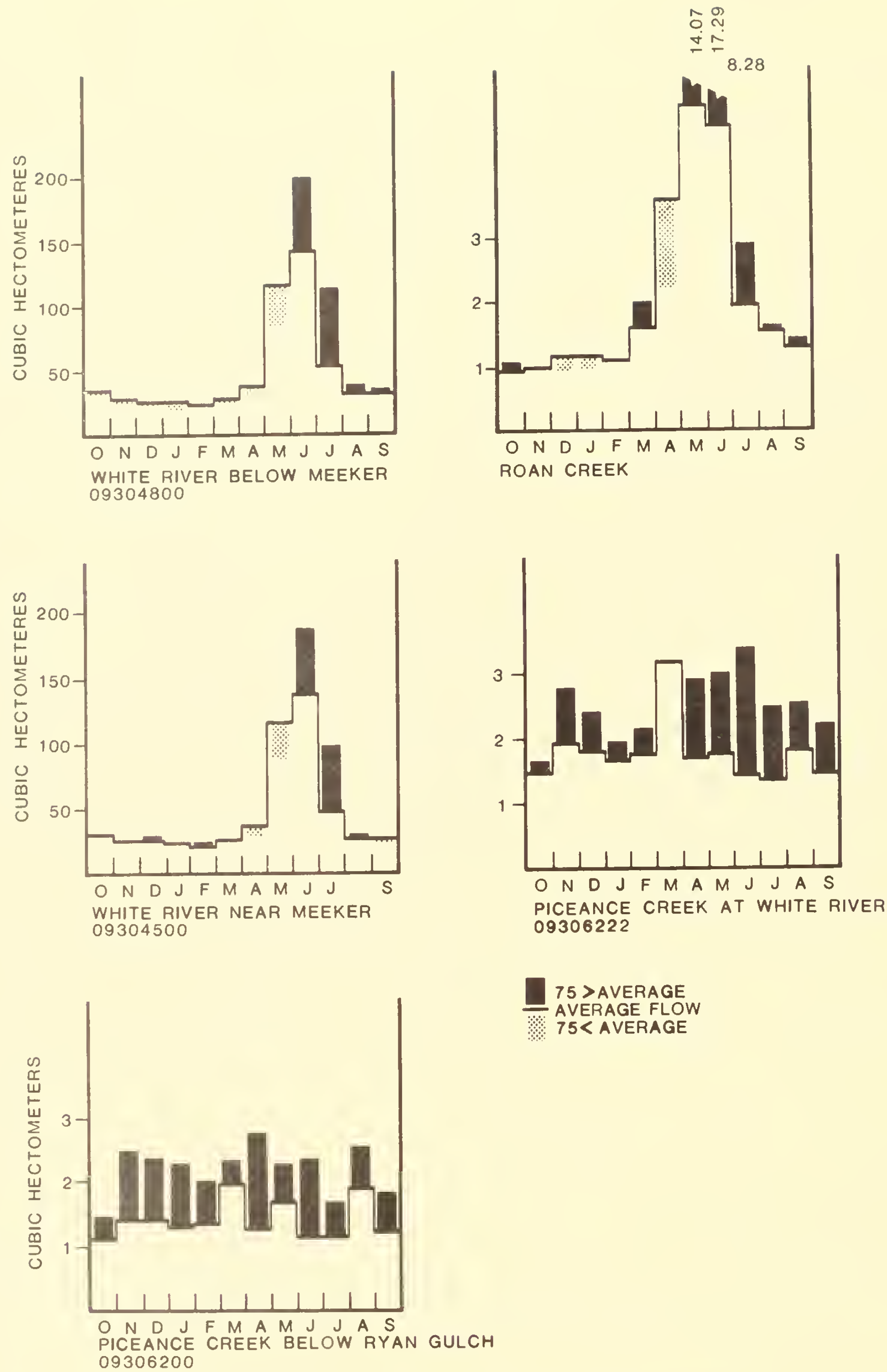
FIGURE 2-20

MAJOR GAUGING STATIONS ON PICEANCE CREEK
WHERE SURFACE-WATER
DATA ARE COLLECTED

Table 2-6

YEARLY DISCHARGE SELECTED WATER GAUGING STATIONS
PICEANCE BASIN REGION
(Acre-Feet)

	Roan Creek 09095000	White River near Meeker 09304500	White River below Meeker 09304800	Piceance Creek at White River 09306222	Piceance Creek below Ryan Gulch 90306200
1965	26,280	500,700	537,200	12,400	11,230
1966	16,230	229,900	328,700	11,880	9,470
1967	10,840	341,900	377,100	---	6,010
1968	25,970	405,400	434,500	---	9,470
1969	46,080	417,100	453,300	---	13,800
1970	18,540	492,200	524,900	---	16,830
1971	11,410	479,400	504,200	12,580	11,910
1972	10,290	399,700	434,400	9,520	7,940
1973	---	491,700	529,800	23,580	21,100
1974	---	450,800	481,100	24,730	19,800
1975	37,450	500,400	524,500	24,570	21,170



MONTHLY AVERAGE STREAM FLOW

AT SELECTED STATIONS IN PICEANCE CREEK BASIN

FIGURE 2-21 WITH MONTHLY FLOW FOR 1975

The only month on the Piceance Creek watershed when discharge was not greater than the average was at Piceance Creek at White River (09306222) in the month of May, where 1975 discharge equaled the average. This might be expected after study of Table 2-6 since the discharge every year after 1972 at all stations is greater than the average discharge as of the end of the 1972 water year. This pattern is more pronounced for the Piceance Creek stations where yearly discharges, since 1973, are double the average. While discharges on the White River since 1972 are greater than the 1972 average, they are not significantly greater and it is assumed that the circumstances that caused the doubling of the discharge in the Piceance Creek watershed were not operative on the White River.

As can be seen in Figure 2-21 the White River 1975 discharge was significantly greater than the average in June and July. Precipitation records for stations within the upper White River drainage show substantial and greater than average amounts of precipitation in these months. For example, the precipitation gauge at Little Hills recorded 1.75 inches in June and 3.00 inches of rainfall in July. The Meeker station recorded 1.70 inches for June, 2.05 inches for July; the Marvin Ranch station recorded 1.25 inches for June and 2.50 inches for July.

The Roan Creek USGS surface water gauging station showed a significant increase over average flow for May and June 1975. This increase in surface flow is not reflected in significantly increased precipitation for May and June in those stations located in the Upper Colorado watershed. However, precipitation gauges are scattered and their records might not reflect late spring precipitation in the Roan Creek watershed.

The hydrographs of monthly average flow at the stations on the White River, Piceance Creek, and Roan Creek (Figure 2-21) present the hydrographic pattern of the various watersheds.

Stream flow patterns in the Piceance Creek drainage basin are typical of those regions where snowmelt is a significant form of stream flow. Precipitation for the months of November through March is stored in the snowpack at the higher altitudes of the basin and becomes available for ground water recharge and runoff as solar radiation and daily temperatures increase in the spring. Snowmelt produces a period of high stream flow, starting in March or April and continuing through June or July. Stream flow for the remainder of the year is maintained almost totally by ground water discharge, which moves through the alluvium into the stream channels or appears as springs along the valley floors. Evapotranspiration rates are high during the summer and most of the precipitation that occurs during this period is used by vegetation or evaporated. Little of this precipitation is ponded or stored and virtually none is lost to deep percolation or soil moisture since soil moisture approaches the wilting point at the end of the growing season. Only high-intensity thunderstorms, which are

usually limited to a small area, produce any significant contributions to summer stream flow.

Mean daily stream flow reaches a peak during the snowmelt period of March through June, recedes through the summer months, and is normally at a minimum during the winter months. This pattern is shown by the 1975 water year hydrograph for Piceance Creek below Rio Blanco (09306007) in Figure 2-22. Stream flow at this gauge is only slightly affected by irrigation. Monthly flow records from other springs and tributary streams in the Piceance Creek basin show a similar pattern.

The hydrographs of average monthly discharge shown in Figure 2-21 for Piceance Creek below Ryan Gulch (09306200) and Piceance Creek at White River (09306222) show a somewhat different pattern because of the effects of irrigation diversion. Approximately 5100 acres are irrigated above the gauge at the White River; this includes 4000 acres above the gauge below Ryan Gulch. The low flows in April at both gauges reflect that large volumes of water are diverted in the early part of the irrigation season.

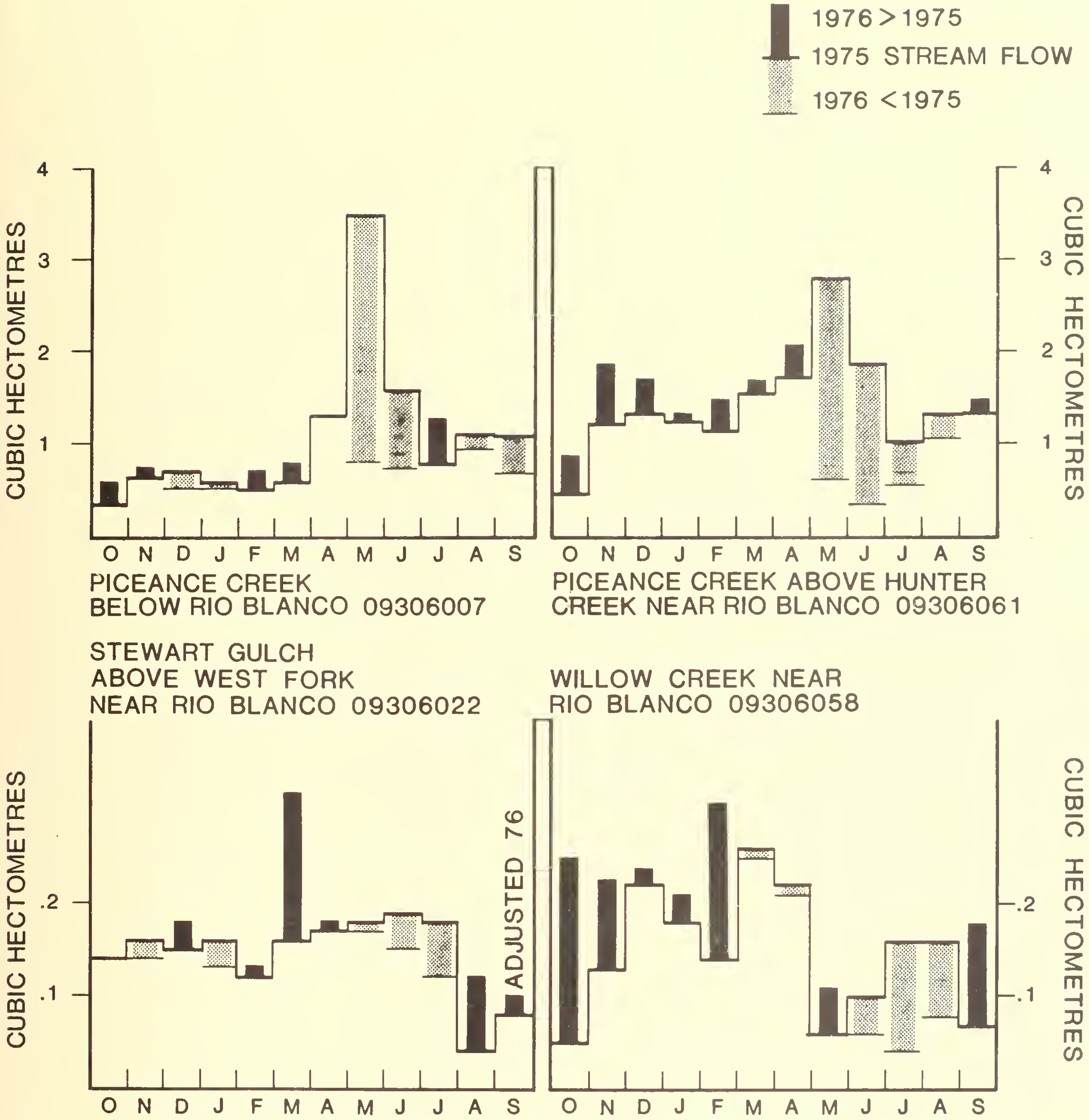
2.3.2.3 Surface Water Quality

Historically the Colorado River has carried a large load of dissolved minerals, quantities considerably higher than in most other major rivers. Several natural factors are responsible for the high salinity; man compounds the problem to some degree through irrigation practices and other uses. Detrimental effects caused by rising salinity levels in the lower Colorado River have resulted in a need for international treaty commitments with Mexico.

Chemical analyses of water samples collected from various locations indicate that the surface waters in the lower reaches of Piceance Creek can be classified as a mixed sulfate-bicarbonate type (Figure 2-23).

The change in ionic constitutents is quite marked proceeding downstream (Figure 2-19). A significant increase in total cations (or anions) occurs below Ryan Gulch and is maintained to the White River. Values for all anions increase downstream. However the concentration of calcium decreases as all other cations increase. This latter change is illustrated better in Figure 2-24. There is a decrease in calcium concentration below Piceance Creek at Ryan Gulch that continues to the White River. This is shown in both average figures and the figures for May 1975.

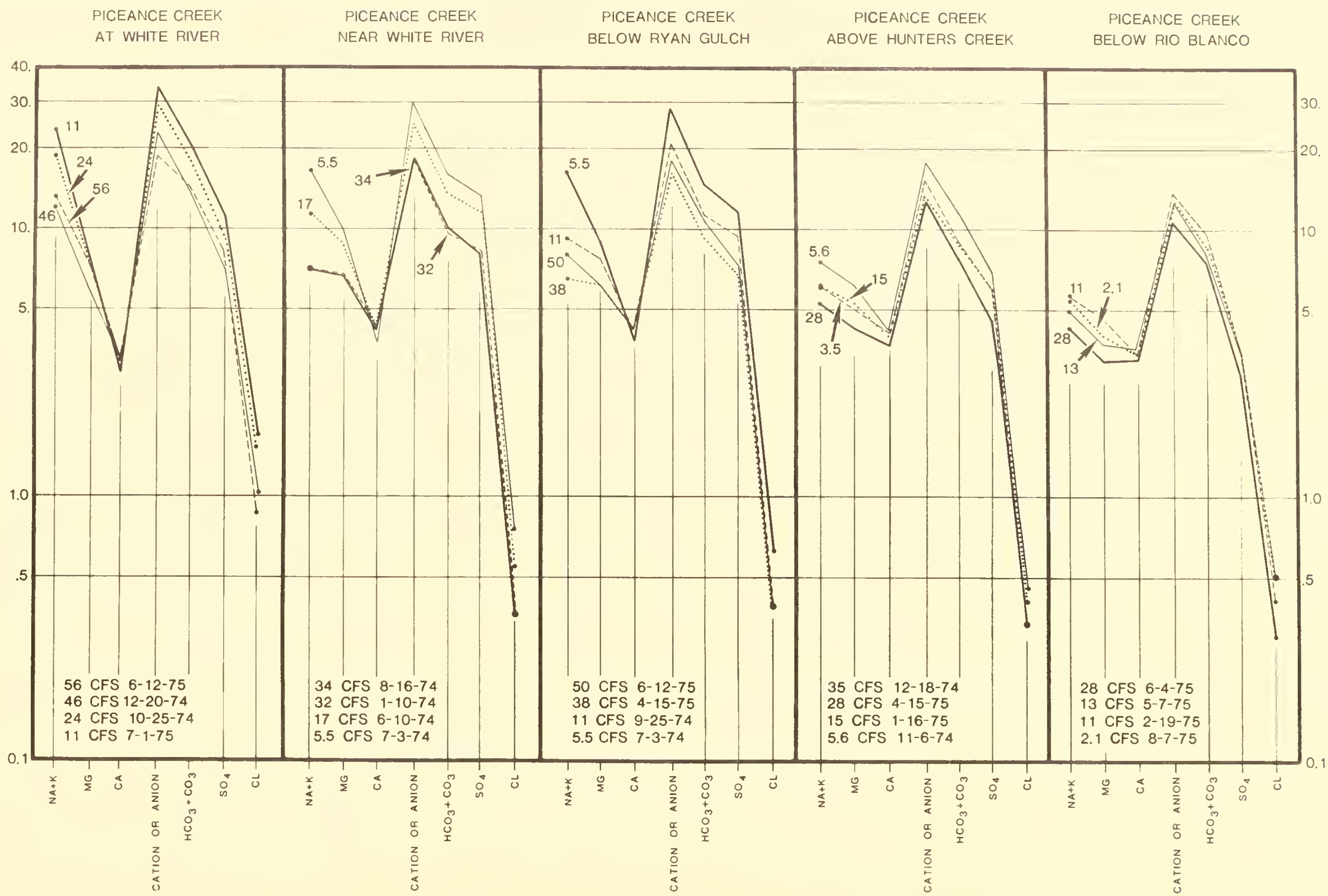
The TDS increases in Piceance Creek from about 700 mg/l, just upstream of Tract C-b, to about 950 mg/l below the Tract. The TDS are approximately 1800 mg/l at the mouth of Piceance Creek.



MONTHLY STREAM FLOW FOR STATIONS ON PICEANCE CREEK

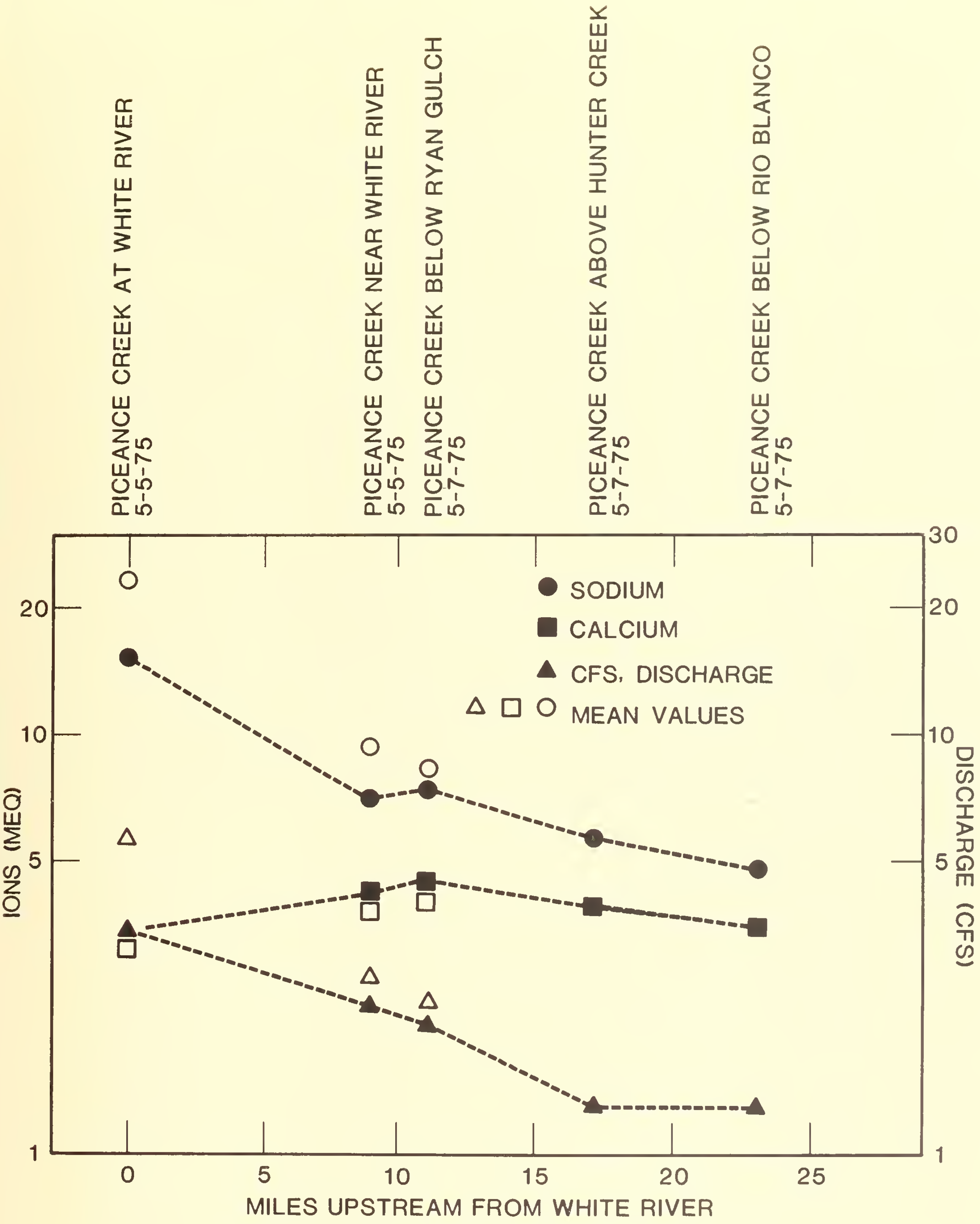
AND TRIBUTARIES NEAR C-b OIL SHALE TRACT

FIGURE 2-22



IONIC COMPOSITION OF WATERS
ALONG PICEANCE CREEK

FIGURE 2-23



CHANGE IN CALCIUM, SODIUM, AND DISCHARGE FROM
U.S.G.S GAUGE 09306007
TO MOUTH OF PICEANCE CREEK AT WHITE RIVER

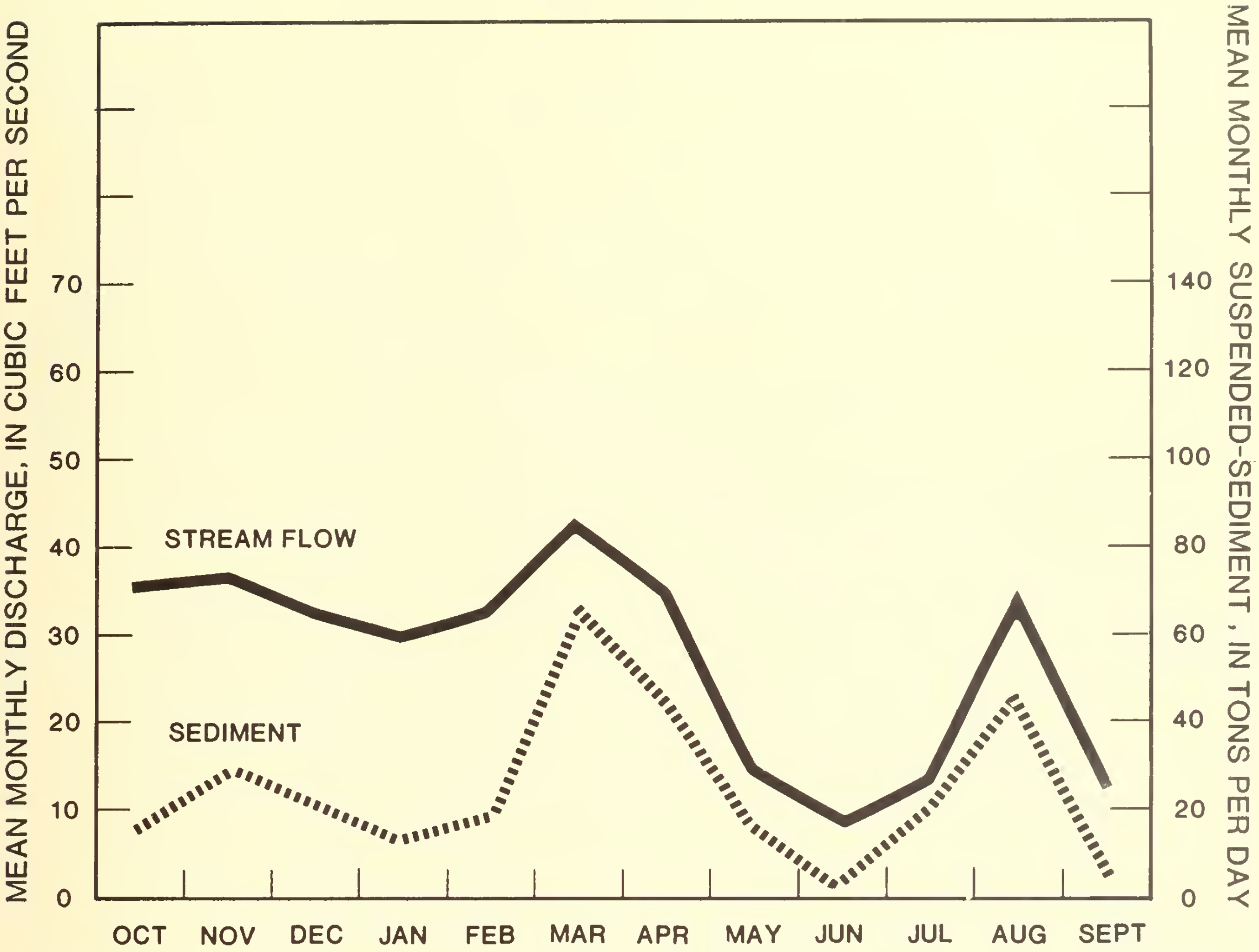
FIGURE 2-24

The concentration of dissolved solids varies throughout the year. During the high-flow period, the dissolved solids concentration decreases because of dilution from snowmelt runoff. During the low-flow period, the concentration of dissolved solids increases because of the effects of irrigation return flows and ground water discharge.

Numerous springs occur in the reaches of Piceance Creek between Ryan Gulch and the White River; several discharge water that has high concentrations of dissolved constituents. For example, the concentration of dissolved solids in the water from Spring S1 (Figure 2-20) was 2610 mg/1, and from Spring S2, it was 22,100 mg/1 (Weeks et al. 1974). These samples were collected in June 1973. The water chemistry of both springs is affected by ground water that moves upward from the Parachute Creek member of the Green River Formation, through the Uinta Formation to the stream valley (Weeks et al. 1974). This demonstrates in part the natural degradation of Piceance Creek.

In the upper reaches of Piceance Creek, water-quality analyses indicate that the sulfate and dissolved solids concentrations exceed the limits of 250 mg/1 (5.2 meq/1) and 500 mg/1, respectively, established in 1962 by the U.S. Public Health Service (USPHS) for public water supplies. Water in the lower reaches of these streams is unacceptable for domestic use by these standards both because of high TDS and because fluoride concentrations exceed twice the optimum limit of 1.0 mg/1 established by the USPHS (1962). Based on a dissolved solids limit of 5000 mg/1, the water in both creeks is acceptable for livestock watering during all but the lowest summer flows.

Suspended sediment discharge from Piceance Creek has been monitored at the gauge below Ryan Gulch since October 1972. Samples are automatically collected on a daily basis and, during a rise in stage, the sampling frequency is increased. Analysis of the 1974 water year data gives a total suspended sediment discharge for the year of about 9,400 tons, or about 0.03 tons per acre for the drainage area. Figure 2-25 shows the mean monthly suspended sediment discharge for the 1974 water year and its relationship to mean monthly runoff. Maximum sediment discharges commonly occurred during the high snowmelt runoff period in March, when the mean daily concentrations ranged from 1000 to 1800 milligrams per liter (mg/1). High sediment concentrations were also recorded for thunderstorms during July and August, with maximum concentrations in July reaching 16,000 mg/1. Daily concentrations in August ranged between 360 and 960 mg/1. For the period of record to 1974 maximum daily sediment concentrations occurred on July 12, 1974 (16,000 mg/1) and minimum daily concentrations of 30 mg/1 occurred on April 22, 1973. Sediment load reached a maximum daily figure of 1010 tons on May 26, 1973 and a minimum daily load of 0.64 tons on July 8, 1974.



SOURCE: U.S. GEOLOGICAL SURVEY (1975)

SUSPENDED -SEDIMENT DISCHARGE AND RUNOFF

FOR PICEANCE CREEK BELOW RYAN GULCH,

1974 WATER YEAR

FIGURE 2-25

Short-term studies conducted by the Colorado Department of Health showed that the dissolved oxygen content of Piceance Creek fluctuates on a diurnal basis (Colo. Dept. Health 1974). The Department concluded that the potential productivity of the water is high for algae, but is not high for fish life. Much of the substrate of the channel is silty and muddy and would not support a large indigenous trout population. Ranchers along the creek have periodically stocked the area for local benefit, and so non-indigenous rainbow trout occur locally.

2.3.2.4 Surface Water on Tract C-b

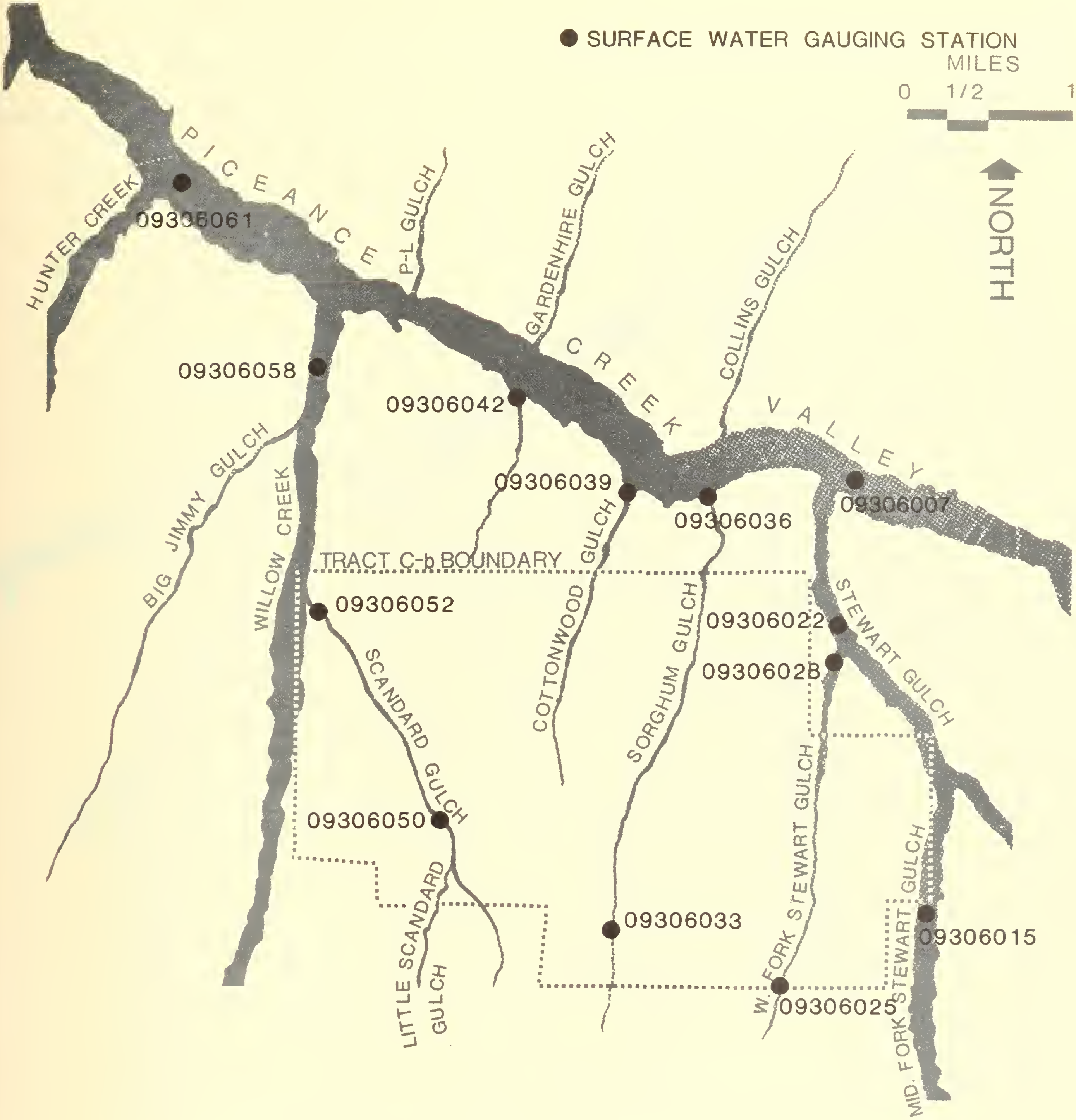
In the vicinity of the Tract, two major perennial streams, Willow Creek and Stewart Creek, flow into Piceance Creek. Prior to the issuance of the Lease, no stream-gauging stations had been established on either of these streams.

Willow Creek borders the Tract to the west (Figure 2-26). Several large springs south of the Tract provide significant flows to this creek (Figure 2-27); some of the water enters the alluvium along the creek bottom and thus locally disappears from the surface system. Willow Creek is perennial throughout most of its length from the headwater drainage area of East Fork Willow Creek to its mouth near the Tract. A major ephemeral tributary to Willow Creek is Scandard Gulch, which passes through the western portion of the Tract.

The Stewart Gulch drainage system is located along the eastern edge of the Tract and also extends south of the Tract. Most of the channels are ephemeral and generally are dry. Perennial flows are found in the main stem of Stewart Gulch and for short reaches on the West Fork Stewart Gulch. Flow in the main stem originates from a seepage area approximately one mile upstream from the junction with the West Fork.

Other drainages on the Tract include Sorghum Gulch, Cottonwood Gulch, and the unnamed gulch west of Cottonwood Gulch. All of these are ephemeral tributaries to Piceance Creek and are generally dry. Flow occurs only from snowmelt or from local thunderstorms. On these drainages very little data have been recorded because the flow events are very infrequent and of short duration.

On the C-b Tract all waters have quite high concentrations of dissolved solids. The tributaries to Piceance Creek are higher in dissolved solids than the main stream. Loading of Piceance Creek across the Tract is noticeable when comparing the concentrations of dissolved solids recorded at USGS Station 09306007 above the Tract and USGS Station 09306061 below the Tract. The former has a mean dissolved solids content of 705 mg/1; the mean dissolved solids content below the Tract is 915 mg/1. Concentrations of



TRACT C-b SURFACE

FIGURE 2-26 WATER GAUGING STATIONS

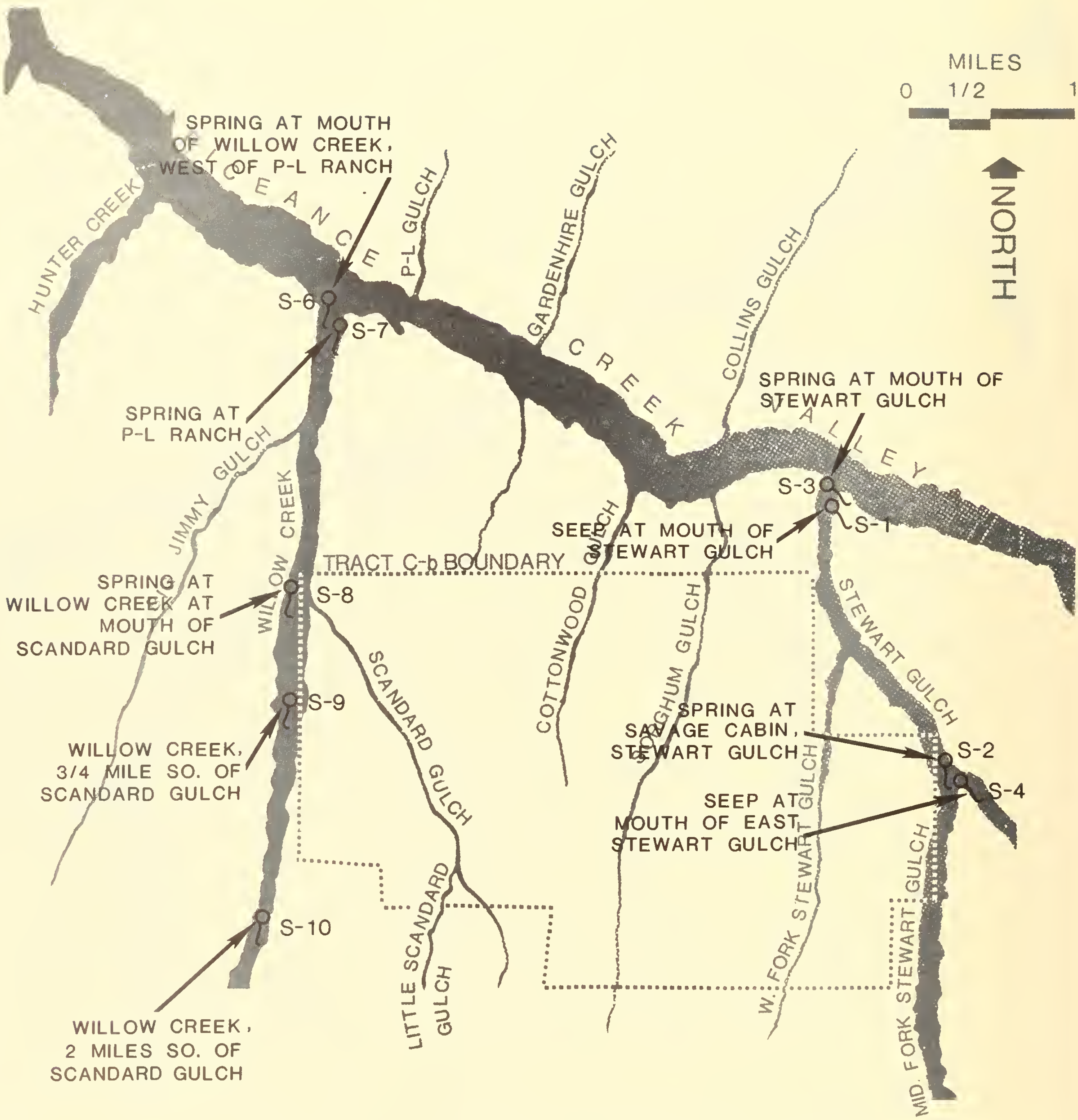


FIGURE 2-27 SPRINGS AND SEEPS TRACT C-b AREA

major constituents in the surface streams are similar to those in the alluvial wells, which indicates the close relationship between ground water flow in the alluvium and baseflow in the streams.

A more detailed discussion of surface water can be found in Volume II of this report series.

2.3.3 Ground Water

2.3.3.1 Geology and Ground Water Occurrence

The stratified nature of the rocks of the Piceance Basin results in a sequence of flat lying layers of sedimentary rocks that vary greatly in porosity and in horizontal and vertical permeability. Ground water occurs in several strata throughout the Piceance Basin. The principal water bearing zones are in the Uinta and Green River Formations; the underlying Wasatch Formation has very little permeability and a general lack of primary and secondary porosity.

The Green River Formation has been divided into several lithologic units based on depositional history. The Garden Gulch member, comprising marlstone and lean oil shale, yields very little water to wells. It is relatively impermeable and forms the lower boundary of the aquifer system in much of the Piceance Basin. The overlying Parachute Creek member contains the most permeable rocks in the Green River Formation. Wells open to the Parachute Creek yield as much as 1000 gallons per minute (gpm) (63.1 liters per second (1/s)) with large drawdowns for short periods.

The Uinta Formation overlies the Parachute Creek member and forms the surface rock over most of the basin. Wells completed in this Formation yield as much as 300 gpm (18.9 1/s) although yields less than 100 gpm (6.3 1/s) are more common. Coffin et al. (1968) reported yields as high as 500 gpm.

The major natural impact on the persistence of such layers and their hydrologic properties is faulting. Faults can provide a much higher than average vertical and horizontal permeability. Fault zones, in fact, can become hydraulic conduits. In addition, faults are of major importance in the mineability of a stratum and in the effect of mining on hydrology.

Major faults in the area are the Piceance Creek fault associated with Piceance Creek dome, and those faults associated with Sulphur Creek dome. Most faults are steeply dipping normal faults and may serve to be a hydraulic connection between all ground water hydrologic zones along Piceance Creek.

In 1974, USGS studies (Weeks 1974 and Weeks, et al 1974) suggested that there are two major aquifers separated by the Mahogany zone. The upper aquifer consists of the Uinta Formation and Upper Parachute Creek member of the Green River Formation.

The lower aquifer consists of fractured and leached marlstones of the lower Parachute Creek member. The porosity and permeability of these aquifers is mostly the result of fracturing; however, in the Uinta Formation, primary porosity does play a role in fluid movement.

The Mahogany zone, shown in Figure 2-28, is a thick interval of rich oil shale 100 to 200 feet thick. Weeks et al. (1974) assumed that only a layer 3 to 10 feet thick within this zone acts as the confining layer; this unit consists of 80-gallon-per-ton shale and persists throughout the basin. Based upon detailed information generated by the program on the C-b Tract, this hypothesis will have to be reformulated and tested for applicability on a local basis.

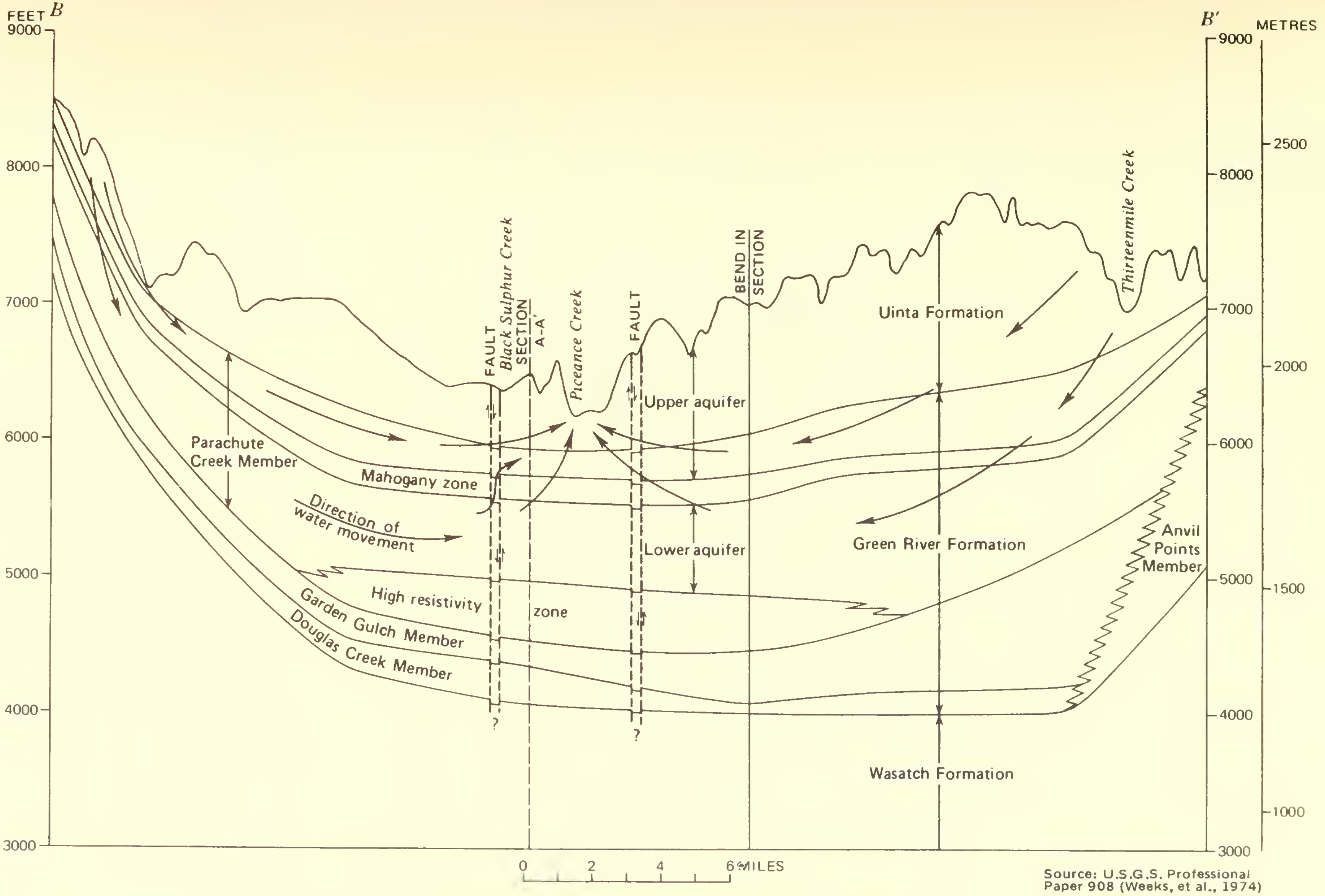
The alluvium is a source of water in the perennial stream valleys and some ephemeral stream valleys. Being confined to stream bottoms, the alluvium is much less extensive than the older aquifers. The thickness of the alluvium is as much as 140 feet (43 meters) and the alluvium is generally saturated below stream level where streams are flowing. Well yields as large as 1500 gpm (95 l/s) (Coffin et al. 1971) have been reported but the alluvial aquifers are of limited extent and high discharge rates can be maintained only for brief periods.

2.3.3.2 Geohydrology

The principal aquifers in the Piceance Basin are in the Uinta and Green River Formations. The principal aquifer system consists of two aquifers separated by a confining layer as shown in Figure 2-28. Discharge from the bedrock aquifers is mainly to the alluvium along the perennial streams.

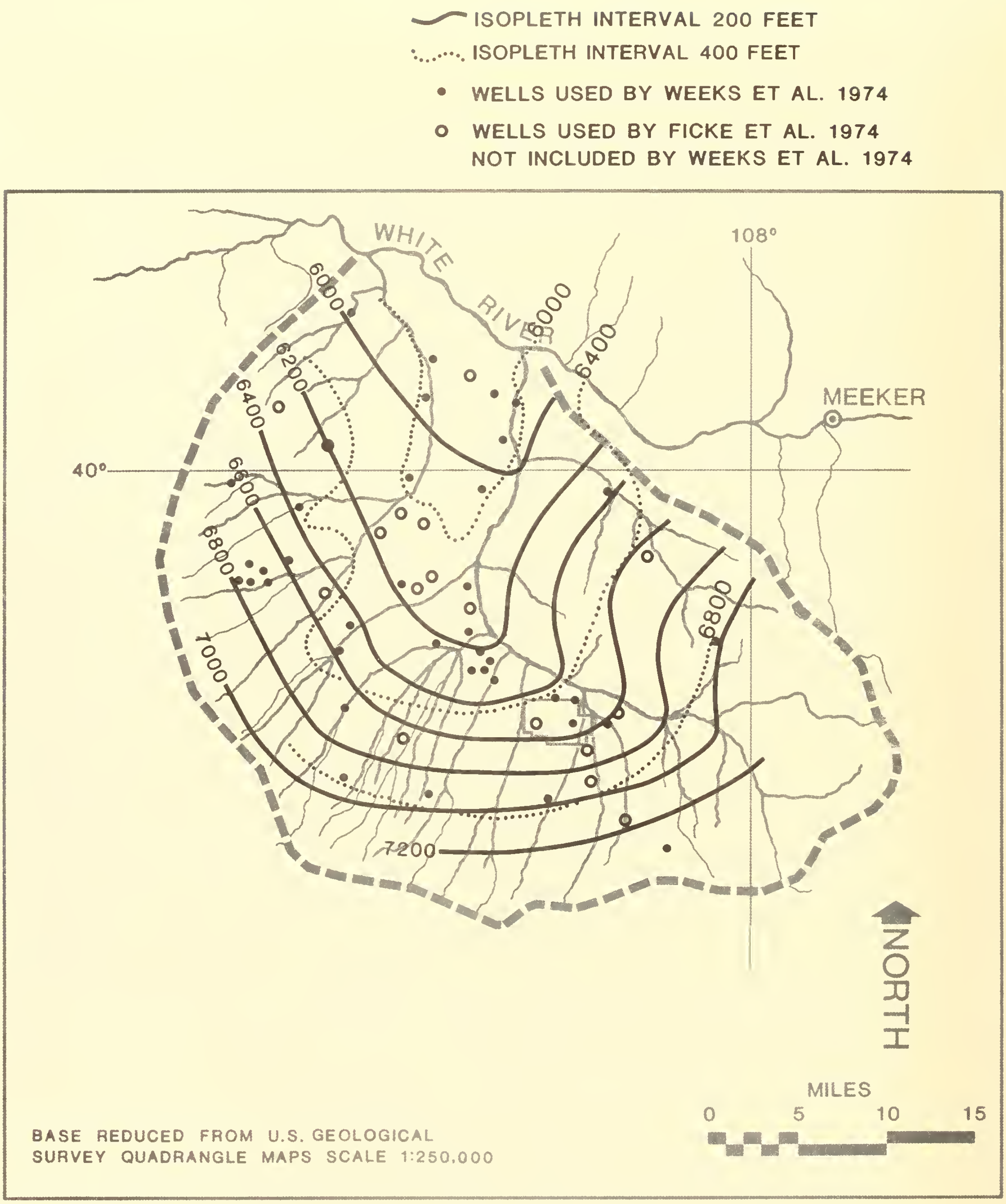
The USGS studies defined ground water movement by mapping the potentiometric surface (Figure 2-29). In general, ground water movement is at right angles to the contours and essentially parallels the stream courses. The overall movement is to the north. Figure 2-29 indicates the amount of movement from June-October 1972 to April 1974. If the data are accurate, some changes have occurred in the Yellow Creek drainage during this period.

Most recharge to the aquifer system comes from spring snowmelt. In the recharge area the water percolates downward, charging the aquifer system, then moves laterally toward the discharge system. The volume of ground water in storage in the Piceance Creek basin has not been accurately determined. Coffin, Welder, and Glanzman (1971) estimated that the volume of water stored in the leached zone was 2.5 million acre-feet. Other estimates have been as high as 25 million acre-feet of water stored in the Green River and Uinta Formations in the Piceance Creek basin.



GEOHYDROLOGIC SECTION THROUGH THE PICEANCE BASIN SHOWING RELATION OF THE AQUIFERS TO THE GREEN RIVER AND UINTA FORMATIONS

FIGURE 2-28



SOURCE: FICKE, ET AL. 1974/WEEKS, ET AL. 1974

POTENTIOMETRIC SURFACE, GREEN RIVER FORMATION
(BASED ON WELLS OPEN
TO BOTH UPPER AND LOWER AQUIFERS)
PICEANCE CREEK BASIN, COLORADO

FIGURE 2-29 JUNE-OCTOBER 1972 AND APRIL 1974

2.3.3.3 Ground Water Hydraulics

Weeks et al. (1974) determined the hydraulics of the basin from 26 wells (Figure 2-29). In general they found, from highly variable data, that the storage coefficient for the upper aquifer was in the order of 10^{-3} and upper aquifer transmissivities ranged from 8 ft^2/day to 1000 ft^2/day. Transmissivities found by Ficke et al. (1974) in two wells in the Yellow Creek drainage were 1580 and 2800 ft^2/day. The nonhomogeneous fractured rock of the upper aquifer system is thin on the west side of the basin and thickens eastward. The transmissivity tends to increase as the thickness increases and Weeks et al. (1974) concluded that the variability in values probably resulted from the small area of influence of the well bore.

Evaluation of the lower aquifer hydraulics was obtained from Weeks et al. (1974) and Coffin et al. (1971). Weeks et al. studied 20 wells, part of the 25 mentioned above. Three of these were used to determine the storage coefficient (in the order of 10^{-4}), and they found transmissivities ranged up to 1940 ft^2/day. Coffin et al. (1971) reported transmissivities in the leached zone of lower aquifer as high as 2700 ft^2/day.

The leached zone is well-developed in the north central part of the basin, and transmissivity is greater there. The transmissivity of the lower aquifer appears to be controlled by the structure of the basin and the occurrence of soluble minerals. Depending on the concentration of dissolved minerals in the ground water, the solution of minerals in the aquifer should increase in the direction of flow; flow is from basin margins toward the north central part of the basin. Thus the transmissivity should increase from the southeast to the northwest along the main structural axis.

In outcrop areas the upper aquifer is unconfined and the specific yield is estimated to be between 10^{-2} and 10^{-1}. In the outcrop areas specific yield of the lower aquifer is estimated at 10^{-1}.

The transmissivities of the alluvial aquifers are highly variable, depending on the saturated thickness and occurrence of silts and clays. Measured transmissivity values ranged from 2700 to 20,000 ft^2/day.

2.3.3.4 Recharge Area

Recharge of the aquifer systems occurs principally from snowmelt during spring. Most of the summer rainfall is lost as direct runoff or it reduces the soil moisture deficiency. Evapotranspiration is extreme and probably little, if any, rainfall infiltrates and percolates to the saturated zone of the ground water system except, perhaps, in the alluvium. Winter snowpack, on

the other hand, is released slowly in the spring when temperatures are low and vegetative growth slow. This would allow the opportunity for infiltration, increasing the moisture content of the soil to field capacity, with subsequent percolation into the saturated zone. The process would be more effective at higher altitudes where snowpack is greater and temperatures lower for a longer period of time. Thus, recharge of the aquifer system of the basin is most effective in areas above 7000 feet (2130 m) where above 65 percent of the November-March precipitation occurs.

2.3.3.5 Discharge Area

In the discharge areas water moves upward from the lower aquifer to the upper aquifer and then is discharged to the alluvium through the valley floors and from springs along the valley walls. The ground water flows through the alluvium to the streams and is discharged as baseflow to Piceance Creek and Yellow Creek or is lost by evapotranspiration.

The Wasatch Formation which outcrops along the White River is of low permeability and probably prevents significant ground water discharge from the Piceance Basin to the White River.

The ground water flow regime of the Piceance Creek basin is illustrated by the potentiometric map (Figure 2-29) which is based on data obtained from wells opened to both the upper and lower aquifer. The altitude of the potentiometric surface varies by more than 1200 feet (365 m).

Because water flows from a higher to lower potentiometric value, flow is from the basin margins to the north-central part of the basin. The pattern of the isopleths on the map (contouring based on very limited data) suggests that Piceance Creek valley may be the principal ground water discharge area in the basin.

2.3.3.6 Water Budget

Ground water development in the Piceance Creek basin has been minimal. The principal use for ground water has been for stock. Wymore (1974) feels there has been little stress placed on the ground water system and it can be thought of as being in a state of equilibrium, i.e., the rate of discharge equals the rate of recharge. This may have been true prior to the nuclear test project, Rio Blanco on May 17, 1973. Surface water flow at Piceance Creek below Ryan Creek and at several springs, where data are available, indicate a significant increase in flow after that date. At the present time data are insufficient to allow the substantiation of the cause of this increase.

Ground water is discharged from the basin in the form of run-off (baseflow) and evapotranspiration. In the semi-arid Piceance Creek basin, baseflow is the major component of the mean annual discharge from the basin. Most evapotranspiration occurs in the bottomland areas where phreatophytic plants occur and pastures and meadows are irrigated.

The ground water budget can be estimated assuming steady state conditions by $G = B + E - P$ where the ground water discharge, G, equals the sum of the baseflow, B, and evapotranspiration, E, minus the precipitation, P, all on an annual basis. Several authors in different reports use similar equations to obtain a water budget but use entirely different figures. Weeks et al. (1974) use 15,650 acre-feet (19.3 hm^3) as mean annual runoff from Piceance and Yellow Creek [a six year average is 15,790 acre-feet (19.5 hm^3)], and assume 80 percent of this is ground water discharge. Their evaporation and precipitation figures are 41,200 acre-feet (50.8 hm^3) and 27,600 acre-feet (34 hm^3); the latter figure represents 14.5 acre-inches of precipitation. Wymore (1974) estimates total precipitation in Piceance Creek basin at 17.40 inches; that of Yellow Creek basin at 15.67 inches. Substituting the figures proposed by Weeks et al. in the above water balance equation gives an estimated total ground water discharge from the basin of 26,100 acre-feet (32.3 hm^3) per year or 31.1 ft^3/s (1.0 m^3/s).

2.3.3.7 Water Quality

The chemical quality of the ground water in the Piceance Creek basin varies between and within aquifers. The quality of the ground water is generally poor and often does not meet all the standards recommended by the United States Public Health Service (1962); in particular it does not meet the limits on dissolved solids (500 mg/l). Nonetheless, ground water is used to water stock and in some instances supply domestic water to ranches. Water quality data for the aquifers is summarized in Table 2-7. The data show that water in the upper and lower aquifers is chemically different, and that water in the upper aquifer and in the alluvial aquifer is chemically similar. The data reported in Ficke et al. (1974) differs somewhat from that reported by Weeks et al. (1974). The greatest differences appear in the lower aquifer. However, inclusion of data from the saline zone would bring the averages from Ficke et al. more in line with those of Weeks.

Analyses of water samples from alluvial wells and springs in the major drainages in the Piceance Creek basin indicate that the water in the alluvium is a sodium bicarbonate type. The concentration of dissolved solids averages 1750 mg/l (Weeks et al. 1974) and generally increases in the downstream direction. The increase

Table 2-7

SUMMARY OF WATER-CHEMISTRY
DATA OF AQUIFERS

Chemical Constituent*	Alluvial -1- Mean	UPPER AQUIFER -1- Minimum	-1- Mean	-1- Maximum	-2- Mean
Sodium	490	55	210	650	290
Potassium	2.5	0.2	1.5	6.0	3.6
Magnesium	80	9.8	60	187	17
Calcium	57	7.4	50	110	13
Bicarbonate	1220	307	550	918	645
Sulfate	430	34	320	850	116
Chloride	42	3.4	16	63	23
Fluoride	4.6	0	1.4	12	8.9
Dissolved Solids	1750	345	960	2180	851

Chemical Constituent*	LOWER AQUIFER -1- Minimum	-1- Mean	-1- Maximum	-2- Minimum	-2- Mean	-2- Maximum	HIGH RESISTIVITY ZONE -2- Mean
Sodium	230	3980	16,000	140	788	7200	10,545
Potassium	0.4	11	78	0.2	2.2	28	28
Magnesium	3.0	9.5	26	<0.01	8.9	58	10
Calcium	2.8	7.4	15	3.4	22.3	28	8
Bicarbonate	493	9100	40,000	397	1762	18,600	19,557
Sulfate	4.2	80	350	10	83	180	139
Chloride	1.3	690	2900	4.3	101	780	3623
Fluoride	5.0	28	66	3.1	15.6	28	37
Dissolved Solids	491	9400	38,900	554	1702	8900	26,140

* Concentrations in milligrams per litre

Source: 1 = Weeks, et al. (1974)
2 = Ficke, et al. (1974)

is the result of irrigation return flows and possible ground water discharge to the alluvium from deeper aquifers in downstream areas, not concentration by evapotranspiration.

The concentration of dissolved solids in water samples from the alluvium ranges from 470 to 6720 mg/l, except at Spring S2 (See Figure 2-20 for location) where the concentration is 22,100 mg/l. Several sampling sites along the lower reaches of Piceance Creek have relatively high concentrations of dissolved solids and Weeks et al. (1974) think that these concentrations may reflect the chemistry of the water discharging to the alluvium from the lower aquifer.

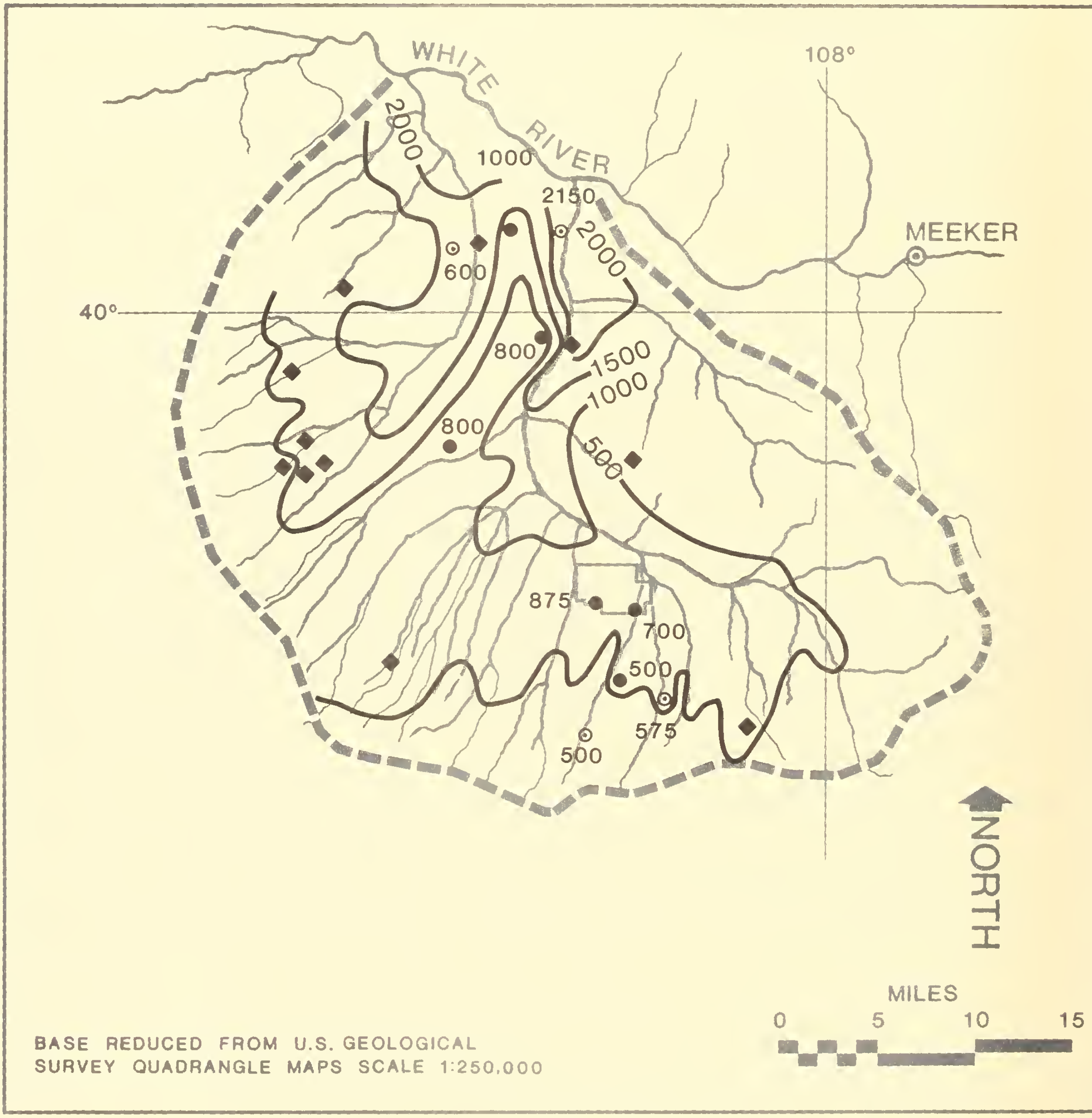
Analyses have been made of water samples collected at 18 locations from the upper aquifer (Figure 2-30) (Weeks et al. 1974). The water in the upper aquifer is classified as sodium bicarbonate type and generally contains moderate concentrations of sulfate and low concentrations of chloride and fluoride. The pattern shown in Figure 2-30 is similar to that of the alluvial aquifer.

Values of the dissolved solids concentration range from less than 400 mg/l to more than 2000 mg/l. Data from Ficke et al. (1974) although taken in 1972 tend to substantiate the pattern shown in Figure 2-30. The potentiometric map presented in Figure 2-29 has a contour pattern similar to that in Figure 2-30, demonstrating that the dissolved solids concentration of the water in the upper aquifer increases in the direction of flow. It is possible that solution of minerals in the aquifer and water moving upward from the lower aquifer increases this concentration. Figure 2-30 also shows the effects of dilution from recharge along the divide between Piceance and Yellow Creeks.

The chemical composition of the water in the upper aquifer varies as it moves from the recharge area to the discharge area. In the recharge area, the ground water is generally a sodium-magnesium bicarbonate type, with sulfate making up nearly 50 percent of the anion concentration. As the water moves toward the north-central part of the basin, sodium and bicarbonate increasingly dominate the ionic concentrations.

Water-quality data have been obtained from water samples collected from 27 wells in the lower aquifer (Weeks et al. 1974). Table 2-7 shows that water from the lower aquifer is a definite sodium bicarbonate type with higher chloride and fluoride concentrations and lower sulfate concentrations than water from the other aquifers. Water from the lower aquifer is extremely low in calcium and magnesium content; the sulfate ion concentration in this aquifer is generally lower than in the other aquifers in the basin. Hydrogen sulfide gas also is present in many samples collected from the lower aquifer. These facts indicate that reducing conditions exist in the lower aquifer, which would

◆ WELL NOT INCLUDED IN FICKE REPORT
⊙ WELL NOT INCLUDED IN WEEKS REPORT
● WELL INCLUDED IN BOTH REPORTS DATUM FROM FICKE
ISOPLETH INTERVAL 500 MILLIGRAMS PER LITRE



SOURCE: FICKE, ET AL. 1974/ WEEKS, ET AL. 1974

FIGURE 2-30

CONCENTRATION OF DISSOLVED SOLIDS
IN THE UPPER AQUIFER
PICEANCE CREEK BASIN

tend to reduce the sulfate and prevent oxidation of the sulfide ion. The average fluoride concentration is 28 mg/l (1.47 meq/l) and was found to be more than 10 mg/l (53 meq/l) in all but one sample; the maximum concentration found was 66 mg/l (3.47 meq/l) (Weeks et al. 1974).

The concentration of dissolved solids in the water of the lower aquifer is moderate to extremely high. Table 2-7 shows that the dissolved solids concentration ranges from less than 500 mg/l to nearly 40,000 mg/l. In one instance, a dissolved solids concentration of 63,000 mg/l in a water sample obtained from the high resistivity zone has been reported. High readings of dissolved solids in the lower aquifer are concentrated toward the mouth of Piceance Creek; readings as low as 600 mg/l TDS can be found toward the basin divide. This is the result of the solution of minerals as the water moves from the basin margins toward the north-central part of the basin. See the pattern of the potentiometric surface shown in Figure 2-29.

The ground water in the lower aquifer contains a significant concentration of many elements. The concentrations of barium, boron, and lithium are consistently high in the northern part of the basin. Here, boron and lithium are present in amounts exceeding the levels determined to be toxic to most plants. Barium is present in the lower aquifer in excess of the 1000 μg/l (0.015 meq/l) value recommended by USPHS (1962) as the limit for drinking water.

The data and interpretations presented by Weeks et al. (1974) in their Piceance Creek hydrologic study were extensively used in setting the regional hydrologic character of the basin and were used as a basis for designing the initial subsurface hydrologic testing conducted on the Tract. As additional tests were performed to better define the aquifer systems, including multiple testing programs, it has been found that the USGS model of the basin is not completely consistent with the new information developed on the Tract. These differences are described in Volume II, Hydrology.

2.3.4 Summary

Surface waters on the Piceance Creek hydrologic basin are a mixed sulfate-bicarbonate type with concentrations of both increasing from the headwaters downstream to the mouth of Piceance Creek at the White River. Discharge patterns are those expected of streams which are sustained during low flow by ground water discharge. Long term monthly averages for nine months of the year at two White River stations and at Piceance Creek below Ryan Gulch vary within 10 cubic hectometers; monthly averages vary within 0.6 cubic hectometers for all months and vary within 0.2 cubic hectometers for nine months of the year. Months of major flow

on Piceance Creek are March through August. Most of the flow during the first part of this period is attributed to winter snowmelt. Flow during the second part of this period is attributed to ground water outflow augmented by summer storms. The ground water regime relies heavily on recharge from winter snowmelt and contributes substantially to the surface flow through discharges from seeps and springs.

Similar quantities of constituents of ground water samples from the upper aquifer and from the alluvial aquifer suggest recharge by the upper aquifer through the alluvium. High concentrations of dissolved solids in the lower aquifer and the high dissolved solids content in certain spring waters suggest communication most probably along faults between the surface and the deeper aquifer.

Ground water chemistry in the deep aquifers on Tract C-b, when compared to the water chemistry of springs and other surface water sources, suggests that there are no conduits between the lower aquifer and the upper aquifer or the surface in this area.

2.4 Soils

2.4.1 Introduction

Soils of the Intermountain Region are classified in four major soil orders: Mollisols, Entisols, Aridisols, and Alfisols (USDA 1975). Mollisols are soils which characteristically form under grasslands and shrublands in arid climates. These soils have a typically high cation exchange capacity and are particularly high in calcium. Entisols are characterized by a lack of horizontal development and may occur under a large variety of climatic conditions and vegetation types. Entisols are termed recent soils; the lack of horizons may be the result of a number of factors, such as accelerated erosion, retarded weathering, or persistent disturbance. Aridisols are soils which develop in arid climates under sparse, xeric vegetation. Aridisols have extremely low moisture regimes, with no available water content, i.e., water held at <15-Bars tension for much of the year, particularly during the growing season (USDA 1975). Alfisols are soils in which silicate clays are translocated. These soils have medium values of available water and provide water for plants throughout the growing season.

Piceance Basin soils have been arranged into four major soil associations composed of a total of 21 soil-series (Figure 2-31, Table 2-8). Taxonomically, the soils are grouped in three of the four soil orders defined above: Mollisols, Entisols, and Aridisols (Table 2-8).

The major controlling factors in soil formation in the Piceance Basin are extremes in diurnal and seasonal temperature; low rainfall; source rock; and the amount of fracturing in the source rock. The controlling factors interact differently, resulting in the development of soils with varying topographic position and bedrock configuration. General temperature and moisture regimes of the Piceance Basin soils are discussed below. All of the soils have their origins in the Tertiary Uinta Formation, which is comprised of interbedded and highly fractured massive sandstones, siltstone, and shale.

The development of upland soils can be partitioned into two categories: 1) shallow soils developing over either massive or highly fractured sandstones, which because of the aridity of the basin undergo little weathering and accumulation of solum; and 2) deeper, fine grained upland soils developing from the same source rock, but altered by eolian deposition and/or historic accumulation of alluvium/colluvium.

GENERAL SOIL AREA MAP PICEANCE CREEK BASIN, RIO BLANCO COUNTY, COLORADO

FIGURE 2-31

Table 2-8

SOILS OF THE PICEANCE BASIN
(USDA CLASSIFICATION SYSTEM, 1975)

Order	Suborder	Great Group	Subgroup	Family	Series
Mollisols	Borolls	Cryoborolls	Pachic	fine-loamy, mixed	Lamphier
			Cumulic	fine-loamy	Silas
			Typic	loamy-skeletal, mixed	Parachute
			Pachic	fine-loamy, mixed	Rhone
			Lithic	loamy-skeletal, mixed	Irigul
		Haploborolls	Aridic	loamy-skeletal, mixed	Veatch
			Torriorthentic	loamy-skeletal, mixed	Mergel
			Lithic	loamy-skeletal, mixed	Castner
		Paleoboroll	Cryic-Pachic	loamy-skeletal, mixed	Northwater
Entisols	Fluvents	Torrifluvents	Ustic	coarse-loamy, mixed (cal.) frigid	Glendive
			Ustic	fine-loamy, mixed (cal.) frigid	Havre
			Ustic	sandy-skeletal, mixed, frigid	Rivra
		Fluvaquent	Typic	fine-loamy, mixed (cal.) frigid	Hagga
	Orthents	Cryorthents	Typic	loamy-skeletal, mixed (cal.)	Vandamore
			Lithic	loamy-skeletal, mixed (cal.)	Starman
		Torriorthents	Lithic-Ustic	loamy-skeletal (cal.) frigid	Rentsac
			Lithic-Ustic	loamy, mixed (cal.) frigid	Redcreek
Aridisols	Argids	Natriargid	Borollic	fine-montmorillonitic	Absher
		Haplargid	Borollic	fine-loamy, mixed	Forelle
	Orthids	Camborthids	Borollic	fine-loamy, mixed	Piceance
			Borollic	fine-loamy, (cal.) frigid	Yamac

Bottomland soils, as well as the intergrades between high and low areas, have developed on coarse alluvial deposits. The intergrades are located on alluvial fans and terraces, as well as on the more gradual slopes. The bottomland soils are relatively thick. Their depth is the result of accumulation of material eroding from the uplands and may be contributed to by rare, and substantial erosional events produced by torrential rains of short duration.

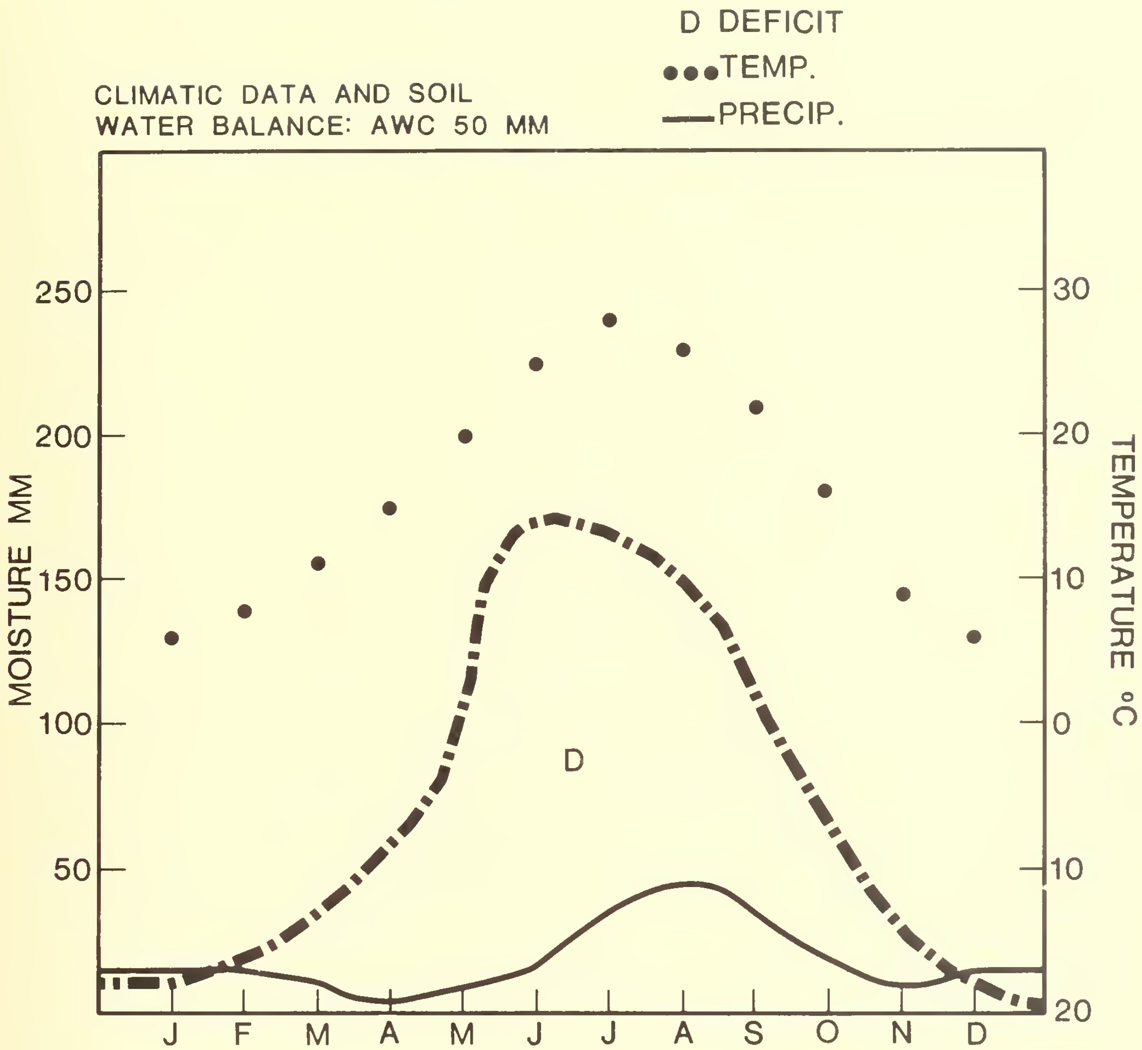
Some of the soils have been altered due to irrigation and crop cultivation. These soils are higher in organics and water content than the uncultivated bottomlands.

Upland soils have also been influenced by man in historic time. The principal agents of this influence are livestock grazing and associated management practices, which may contribute to erodability.

2.4.2 Soils of the Piceance Basin

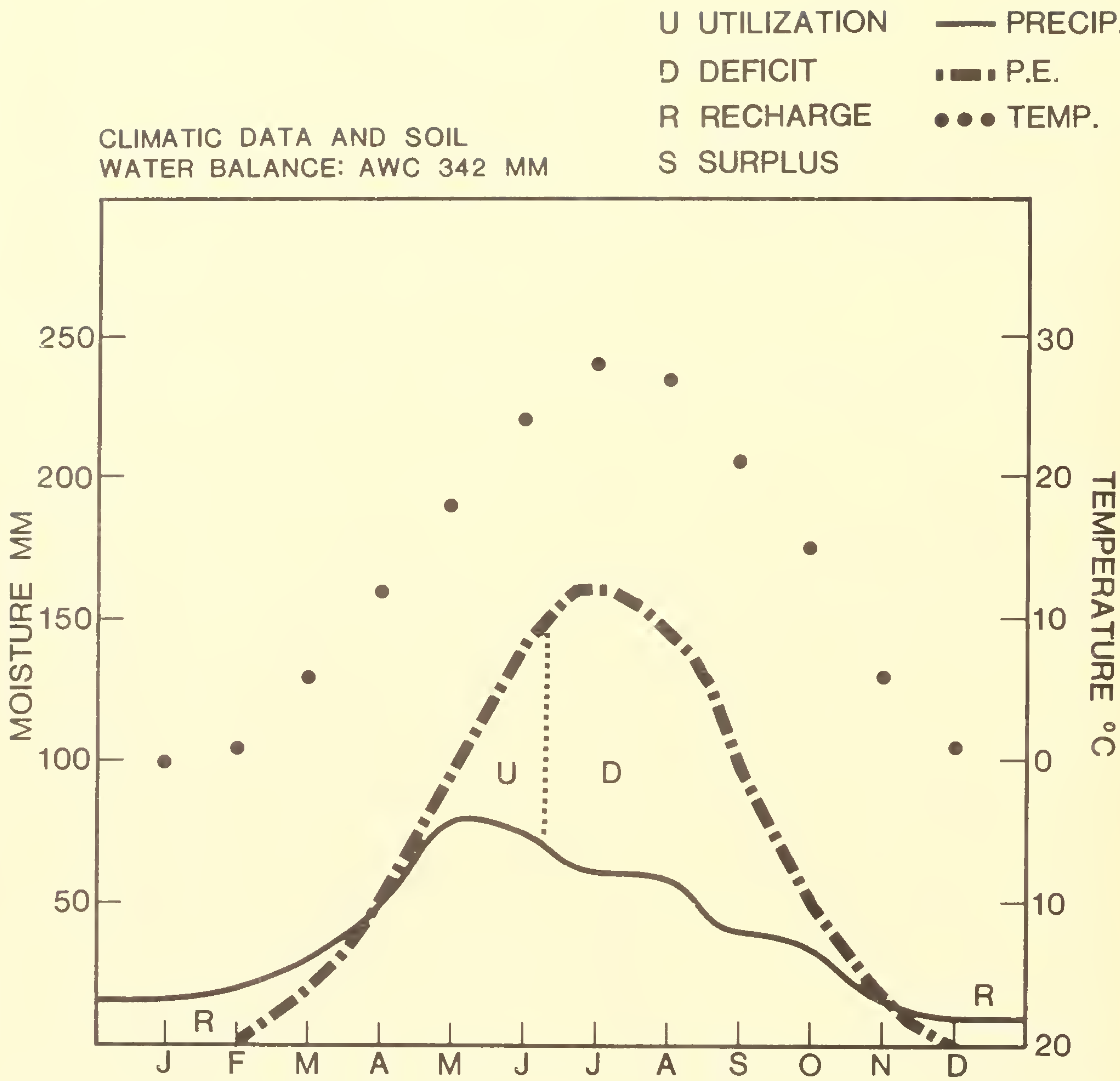
All of the soils found in the basin are cool or cold and have limited available water to support vegetation. Soils in the basin are placed in two categories of temperature, cryic and frigid. Cryic soils have a mean annual temperature greater than 0^{0}C. Frigid soils have a mean temperature of less than 8^{0}C, but are warmer in summer than cryic soils (USDA 1945). Cryic soils in the Piceance Basin include the Cryoborolls, Paleoborolls, and the Cryorthents. Frigid soils are the Torrifluvents, Fluvaquents, Haploborolls, Torriorthents, Natriargids, Haplargids, and Camborthids (Table 2-8).

Three categories of moisture apply to the Piceance Basin soils: torric, ustic, and udic. Torric soils (Figure 2-32) are those that are dry for the greater part of the growing season and are never totally wet. These soils are deficient in moisture for plant growth ($\geq$15-Bars tension). Little or no leaching occurs in these soils as a result of low moisture, and significant salt accumulations may occur. Torric soils include the Torriorthents and Torrifluvents (Table 2-8). Ustic soils (Figure 2-33) have a limited moisture regime, but have surplus (i.e., precipitation exceeds evapotranspiration) of moisture during spring and fall. Some leaching may occur in Ustic soils during these seasons. Sufficient moisture for plant growth may be available in early summer, but mid- and late-summer moisture is limiting. Ustic soils include the Fluvaquents, Haploborolls, Natriargids, Haplargids, and Camborthids (Table 2-8). Udic soils (Figure 2-34) are those in which water is available for vegetation during the growing season. These soils may be dry for short periods of time, but leaching occurs for most of the year. Precipitation and evapotranspiration are approximately equal in regions where udic soils occur; soil tension rarely exceeds 1-Bar (USDA 1975). Udic soils in the Piceance Basin are the Paleoborolls, Cryorthents, Cryoborolls, and the Haploborolls (Table 2-8).



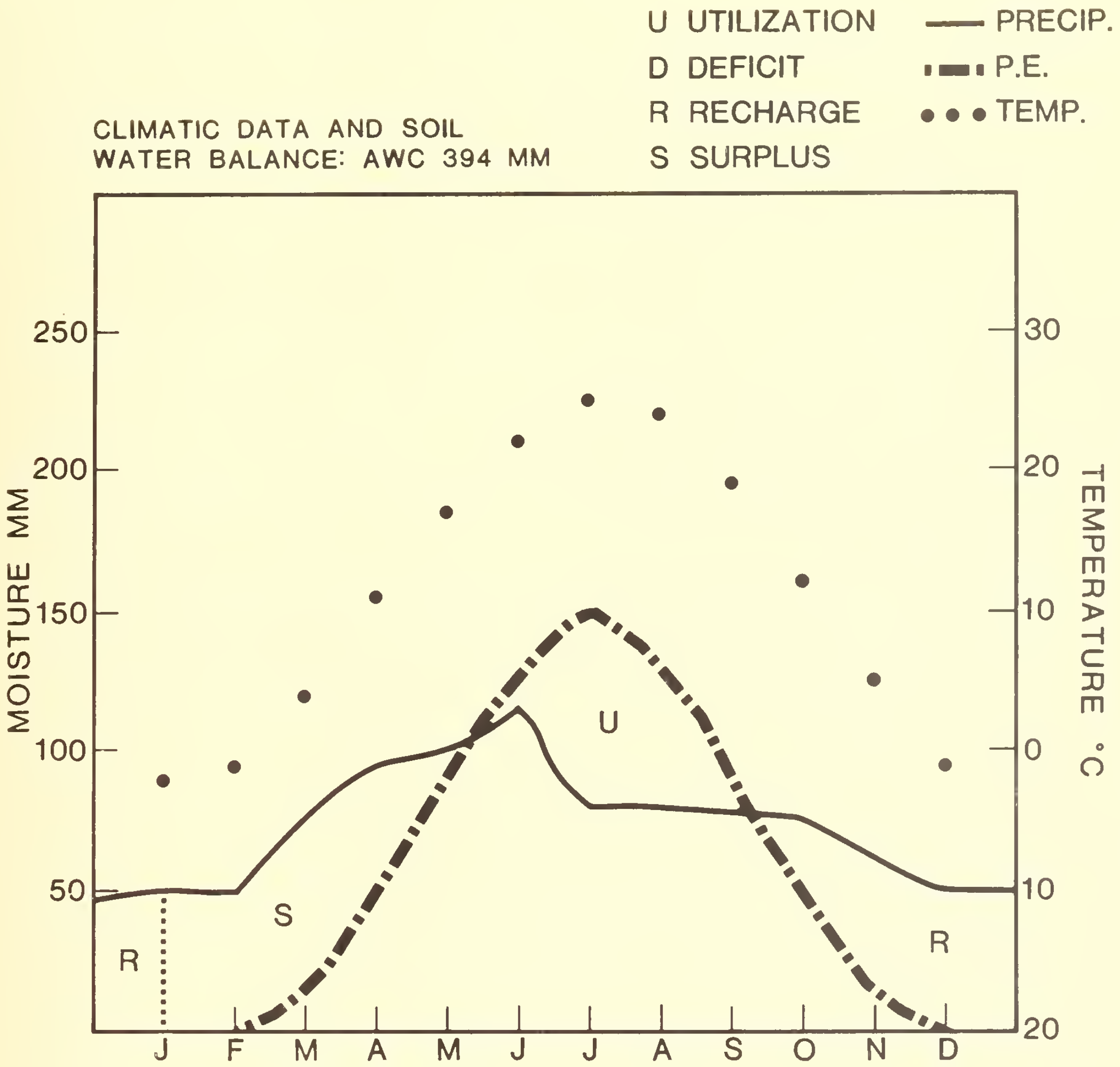
CLIMATIC DATA AND SOIL WATER BALANCE
FOR A SOIL THAT HAS AN ARIDIC SOIL MOISTURE REGIME,
AFTER U.S.D.A. 1975

FIGURE 2-32



CLIMATIC DATA AND SOIL WATER BALANCE
FOR A SOIL THAT HAS AN USTIC SOIL MOISTURE REGIME,
AFTER U.S.D.A 1975

FIGURE 2-33



CLIMATIC DATA AND SOIL WATER BALANCE

FOR A SOIL THAT HAS AN UDIC SOIL MOISTURE REGIME,

AFTER U.S.D.A. 1975

FIGURE 2-34

The four soil associations mapped for the Piceance Basin (Figure 2-31) are described below as to physical, topographical, elevational, and vegetation features. Vegetation associated with these soil groups are also shown in Table 2-9. The number by each association name indicates the soil mapping unit. Each of those associations is a landscape unit that has a distinctive proportional pattern of soils. Each association consists of several major soils and several minor soils. The soils in one association may occur in another association but in a different pattern and relationship.

Table 2-9 SOIL AND VEGETATION ASSOCIATIONS IN THE PICEANCE BASIN

Soil Type / Vegetation	53	97	132	133
Bottomland Sagebrush	X		X	X
Desert Shrub			X	X
Upland Sagebrush	X	X	X	X
Mixed Mountain Shrub	X			X
Pinyon-Juniper Woodland	X			X
Grassland		X		
Forest	X	X		

2.4.2.1 Parachute-Rhone-Irigul Soils (53)

These soils make up a soil association which occupies the upper reaches of the creeks which extend back to, or near to, the Garfield County line or the Cathedral Bluffs.

The Parachute soil is the most extensive in this association. It is intermediate in depth to the deep Rhone soils and the shallow Irigul soils. All those soils are underlain by hard rock. Included within this association are long, narrow areas of Silas soils which occupy alluvial fans and bottoms in this area. This is the one soil in the association which is generally more than 1.5 meters to bedrock and is probably more than 3 meters in places. Gullies, which are not uncommon in the Silas soil, often expose 2 to 2.5 meters of fine-loamy alluvium.

At the higher elevations and on generally north-facing slopes some Northwater soils are included. Those areas are typically covered by aspen. However, not all aspen sites are underlain by Northwater soil; many are underlain by Rhone or by some included Lamphier soils. Also included in the climatically transitional zone are some areas of Castner and of Veatch and Mergel soils.

2.4.2.2 Vandamore-Starman-Irigul Soils (97)

These are upland soils which for the most part occupy territory from 1.6 to 4 km in width immediately east of the Cathedral Bluffs. The ridge crest here is generally windswept, resulting in less moisture on the crests. The lighter colored Vandamore and Starman soils occupy those positions. The darker colored Irigul soil occupies concave pockets where snow accumulates and remains longer. The chief included soil is Parachute which also occupies swale positions.

All these soils have mean summer temperatures of less than 15^{o}C. They are composed of more than 35 percent coarse fragments, and are underlain by hard rock. Vandamore and Parachute soils are between 50 and 100 cm in depth, but are generally less than 75 cm to bedrock. Starman and Irigul soils are shallow.

2.4.2.3 Glendive-Havre-Hagga Soils (132)

These are deep alluvial soils in the major drainages. These soils occur adjacent to the White River, along Piceance and Yellow Creeks and along tributaries to those creeks. Where delineated along the minor tributaries the included areas are generally between 4 and 13 km long and between 1.2 km and 2.4 km wide. Glendive is the most extensive soil. Along Piceance Creek, however, Hagga soil is more extensive. Havre is generally found in relatively broad and more gently sloping bottoms than is the Glendive soil. Alluvial cones which have axises at right angles to Piceance Creek and such tributaries as Ryan Gulch are largely comprised of Rivra soil. The gullied lower end of Piceance Creek is flanked by the Absher soil, which is notable for its high sodium content.

All these soils are more than 150 cm deep, and all except the poorly to very poorly drained Hagga soil are well drained. Of these soils, only the Rivra is consistently gravelly and even it is commonly stratified, with some relatively nongravelly layers. Slope gradients of all these soils are mostly less than 9 percent.

2.4.2.4 Rentsac-Piceance-Yamac Soils (133)

These are upland soils occurring mainly at elevations between 1830 and 2255 meters. They developed under a mean annual precipitation equivalent to about 406 mm of rain.

By far the most extensive soil in this association is the shallow and flaggy Rentsac soil. Some relatively localized areas, however -- most notably the 84 Mesa -- are characterized by much of the deeper, non-flaggy Piceance and Yamac soils.

Included soils are a very shallow and very steeply sloping Torriorthent in juxtaposition with rock-outcrop, and Redcreek or Forelle soils. The rock-outcrop soils which include very shallow Torriorthents, mostly occupy sideslopes associated with drainages which are commonly entrenched 30 meters or more below the general upland surface. Redcreek soils generally occupy shoulders of ridges where the underlying rock is sandstone. Forelle soils, like the Yamac, are more than 100 cm deep, but differ from the Yamac in having a clay loam subsoil. The subsoil tends to slow down internal drainage and for this reason areas of this soil may be detected because of rut formation on unpaved roads.

This soil association includes and in places consists largely of soils which have darker surfaces than the Rentsac soil. One such soil is the Castner which otherwise is very similar to the Rentsac. Other included soils with dark surfaces are Veatch and Mergel. These generally occupy steep to very steep sideslopes. The largest area of these included darker soils is in Townships 2 and 3 South, and Range 96 West. All these soils are underlain by hard sandstone or shale. Depth to hard rock is as follows:

Rentsac (and Red Creek and Castner)	25-50 cm
Piceance (and Veatch)	50-100 cm
Yamac (and Mergel)	100 cm plus, but generally less than 150 cm

Soil components within this soil association are identifiable in part by the native vegetation. Rentsac, as well as the inclusions of Redcreek and Castner soils, generally support stands of juniper or, locally, of pinyon. Sagebrush-grass openings or parks occupy areas of Piceance and Yamac, as well as the included Forelle soils. The climatically transitional zones occupied by Veatch and Mergel soils may be characterized by fairly dense stands of serviceberry together with Gambel's oak.

3.1 Introduction

Federal Oil Shale Lease Tract C-b lies in the Piceance Basin of northwestern Colorado. The montane forests of the Rocky Mountains rise to the east and the cold deserts of the Great Basin and Intermountain West lie to the west at lower elevations. The Piceance Basin flora is comprised of species characteristic of both the Rocky Mountain flora and the cold desert floras; as such the local flora is transitional in nature. The region is characterized by pinyon-juniper woodlands interspersed with shrub communities. In this ecosystem, pinyon pine, Rocky Mountain juniper, and Utah juniper are dominant tree species which grow in open stands mixed with numerous shrub species. Mule deer and other animals are closely tied to the woodlands which are the most extensive habitat type in the region.

The flora and fauna of the region are distributed in a complex mosaic of types controlled by climate, soils, topography, and human disturbance. The region is defined here for convenience as the geographical Piceance Basin with its surrounding land area, and may be characterized as having a semi-arid climate, receiving 12-24 inches of precipitation annually, primarily as winter snowfall and spring rains. The region is bounded by the Colorado River on the south, the White River on the north, Grand Hogback to the east, and Cathedral Bluffs in the west. Many of the plants in the region are adapted to dry conditions. Localized moist conditions, such as those around stream bottoms, support a greater variety of plant and animal species. The Basin is dissected by ridges and valleys which create an elaborate pattern of plant and animal habitats.

The greatest changes which have occurred in the regional biota over the last 10,000 years have probably been those caused by European man. Overgrazing practices of early settlers changed the landscape by elimination of tall grasses and trees in valley bottoms. In modern times, chaining practices have been implemented by the Bureau of Land Management (BLM) to improve domestic livestock and wildlife carrying capacities by increasing range production. As a result, large areas of pinyon pine and juniper trees lie prostrate on some ridgetops, while grasses and shrubs have proliferated in the absence of the tree canopy.

With the recognition of potential energy resources in the region came a greater interest in the biology of the area. Before the 1960's the only well-studied group was the famous mule deer herd. This herd is one of the largest migratory mule deer herds in North America and represents an important sport hunting asset to the State of Colorado. The importance of the Piceance Basin to this herd prompted the State to establish its Little Hills Wildlife Experiment Station in the Basin. Since the 1930's, this station has pursued studies of the ecology of the Piceance Basin mule deer herd and certain other wildlife species. Data from these studies provide the only source of long-term information on the ecology of the Basin.

Recently more attention has been focused on ecosystems as a whole. The pinyon-juniper ecosystem is dominant in northwest Colorado. The associated grass and shrub lands of this ecosystem support important livestock and sport hunting industries. The Utah Agricultural Experiment Station (1975) sponsored a symposium, the purpose of which was to synthesize into technical papers much of the current available knowledge regarding the pinyon-juniper ecosystem. The results demonstrate the lack of data available to representatives of government and industry charged with assessing the environmental impact of man-induced modification within the pinyon-juniper ecosystem. The International Biological Program's (IBP) Desert Biome group has made significant contributions to the understanding of the various ecosystems of this area.

The first attempts to undertake comprehensive ecological studies of Piceance Basin ecosystems and to construct conceptual models of the interrelationships between plant and animal groups have been made by those involved in developing Federal Oil Shale Tracts C-a and C-b.

Studies made of the biota on the C-b multipurpose spur corridor supplemented the Tract C-b biological data. The proposed corridor route extends to the south of the Tract to a higher elevation and includes some habitats not found on the Tract. Information on both the Tract and the corridor provides a well-studied strip across the basin extending from the Piceance Creek bottom to the upper reaches of the Roan Plateau.

3.2 Vegetation

3.2.1 Introduction

The vegetation of the Piceance Basin and surrounding region occurs as a mosaic of vegetation types which conform closely with the ridge and valley topography of the area (Pocket Figure 3-1, refer to pocket inside back cover). In a broad ecological sense, the basin is part of a large expanse of pinyon-juniper vegetation that extends intermittently from southern Wyoming to the southwestern U.S., through Colorado into Utah, New Mexico, and Nevada (Küchler 1964). The pinyon-juniper ecosystem has recently received increased attention by ecologists and government agencies, partly because of increased resource demands in the western U.S. and partly from the need for meaningful land use decisions based on biological data. Studies such as those in the IBP Desert Biome and a recent pinyon-juniper symposium (Gifford and Busby 1975) summarize work done to date and needed research in the pinyon-juniper ecosystem.

Floristically, the Piceance Basin lies in the transition zone between the cold desert floras of the Great Basin and Intermountain West (Cronquist et al. 1972) and the montane forests of the Rocky Mountains (Daubenmire 1943). The mosaic of plant communities characteristic of the basin results from the differing ecological amplitudes of the dominant species, and the influence of climatic and edaphic gradients created by the diverse topography.

3.2.2 History of Botanical Studies

Early accounts by the Escalante expedition, around 1776, indicate that the vegetation of the area was much the same then as now, with areas of open forests and sagebrush (Bolton 1950). Observations made during early cadastral surveys (ca. 1870) dispel many popular myths that upland vegetation is significantly different from pre-settlement vegetation (Hayden 1876) except in the chained areas. Graham (1937) published a study on the flora of the Uinta basin that included results of his collections on several study sites in the Piceance Basin area. His descriptions of the major vegetation types, early history, and plant communities remain one of the most complete accounts of the area despite its rather general nature.

Recent studies of the vegetation of the region include the floristic surveys conducted by Ward et al. (1974), and the detailed

analyses of specific areas by Colony Development Operation (1974), Keammerer (1975), and C-b Shale Oil Project (1975). Ward described seventeen vegetation types in the basin and correlated these types with location along an elevational gradient. Terwilliger (1974) described patterns of natural and artificial rehabilitation within the major vegetation types described by Ward. Vories (1974) made the first rather extensive survey of the flora and plant associations of the Piceance Basin. He classified and described 35 different plant associations and related their distribution to elevation, soils, successional stage, topography, and land use.

Intensive, site-specific studies are being conducted at Federal Lease Tracts C-a and C-b. Vegetation distribution and composition are being integrated with detailed information on soils, geology, topography, climate, and animals. These studies constitute a landmark in the history of understanding all aspects of an ecosystem and building them into a workable model to anticipate impacts of man on the natural world.

3.2.3 History of the Vegetation of Piceance Basin

Present distribution patterns reflect the evolution of a flora through topographic and climatic changes beginning in the Cenozoic era (ca. 60 million years ago). The gradual uplifting of the Sierra-Cordilleras produced a rain shadow effect which caused significant changes in the climate of the continental western U.S., toward a drier, arid and semi-arid condition (Axelrod 1940). Plants which developed during a cooler and moist time retreated to higher elevations and north-facing slopes. Only in early Pleistocene times (ca. 1 million years ago) were the modern plant formations fully segregated into the regional climax vegetation associations with localized communities that now characterize western North America (Axelrod 1948). Except for a few endemic species, most of the plants in the southern Rockies are at the limits of their normal range. They are in a complex transition between four large floristic regions: the Mexican Plateau flora to the south, the Arctic flora to the north, the Great Basin flora to the west, and Great Plains flora to the east (Weber 1965).

3.2.4 History of Climate-Vegetation on Tract C-b

Past and present climates have been studied in detail for the Tract C-b area through analyses of growth rings in trees. The width of growth rings and dendrochronology can serve as a natural record of climatic variation as patterns of precipitation change over time.

A master chronology was produced for the area using pinyon pine (Appendix A). Growth increments were dated with climatic records and show fluctuation in the past and present climate of the C-b area. Twenty-nine trees were used in building the master chronology, which identified consistent diagnositc growth increments. Diagnostic increments are rings which are either extremely narrow or extremely wide. A very dry year produces a narrow ring, whereas a year of high precipitation results in a dramatic increase of ring size. Vertical lines represent the relative thinness of a growth increment; a shorter line is a smaller growth ring. These increments were correlated with precipitation regimes for Meeker and Rifle, Colorado.

The results of these dendroclimatological studies have described the past climatic cycles leading up to the present interpretation of rainfall. The cycles have an average period of eleven years or a multiple thereof. The eleven-year cycle is often bi-modal with an average modal period of six years.

There were five cycles, from 1445 to 1550, with two extremely wet winters occurring in 1462 and 1484. Abnormally dry winters occurred in 1460 and 1550. Schulman (1945) also notes an abnormally dry winter in 1455 which is not seen in C-b data and may be attributed to the initial growth of trees during which time they are relatively insensitive to changes in moisture. Similarly the high value of predicted precipitation in 1440 is attributed to the extremely rapid growth of young trees and the incomplete elimination of growth trend during the analysis.

The 1500's contained ten cycles beginning in 1550 and ending 1598. Abnormally wet winters occurred in 1512, 1523, and 1549. Extremely dry winters occurred in 1506, 1533, 1580, 1590, and 1598. Schulman (1945) notes that the years 1584 and 1585 also had extremely dry winters in the Colorado River Basin. The periods of 1528 to 1534 and 1574 to 1587 were characterized by below-normal winter precipitation.

In the 1600's abnormally wet winters occurred in 1604, 1606, 1652, and 1680. Abnormally dry winters occurred in 1634, 1653, 1685, 1686, and 1704. From 1598 to 1634 the winter precipitation averaged above the mean and was characterized by a 36-year cycle. Other multiple cycles were recorded from 1667 to 1686 and from 1686 to 1704. The climate in the 1600's changed more uniformly and had fewer dramatic fluctuations than did the other time periods.

In the 1700's extremely wet winters occurred in 1720, 1726, 1734, and 1790. Extremely dry winters occurred in 1756 and 1798. The period from 1704 to 1752 was characterized by relatively uniform change demonstrating two multiple cycles in that time span.

In the 1800's abnormally wet winters occurred in 1811, 1841, and 1849; dry winters occurred in 1817, 1824, 1847, 1851, 1863, 1879, and 1889.

In the 1900's wet winters occurred in 1941, 1942, 1947, and 1957; dry winters occurred in 1902, 1919, 1924, 1936, 1959, and 1963. The discrepancy between actual precipitation and predicted precipitation from 1957 to 1961 may be attributed to soil erosion or competition as a direct result of the high amount of winter precipitation. There was an overall increase in winter precipitation from 1959 to 1974.

From 1937 to 1974 there was no long-term trend of generally increasing or decreasing winter precipitation or climatic change. The basic cyclic period of eleven years or multiples thereof were continuous throughout the record.

3.2.5 Past and Current Land Uses Affecting Present-Day Vegetation

The historic effects of man on the vegetation of the Piceance Basin include the removal of sagebrush from bottomland areas, removal of pinyon-juniper overstory by chaining, and the introduction of livestock and exotic plant species. The response of the native vegetation has been an alteration of community composition and structure due to the selective grazing pressures of livestock, and the invasion of exotic plant species on disturbed sites.

The effects of humans on the basin's biota were inconsequential until the early 1800's when fur trappers frequented the basin's streams in search of beaver pelts. Prior to that time, the nomadic Ute Indians utilized the native plants and wildlife of the basin. More extensive use by European man began during the late 1800's when western Colorado was made relatively accessible by the new railroads. Late in the 19th century, the area became a center for beef production. Herds brought from Texas, Arizona, Wyoming, and Utah were summered in the basin and shipped to slaughter houses in Aspen and Leadville during the fall. Overstocking was common, and extensive overgrazing reduced the presence and abundance of certain native grasses and encouraged establishment of species that invade overgrazed ranges. The modified species composition persists and remains apparent today.

Sheep and cattle ranching remains a dominant industry in the basin today. Other uses include exploration and preliminary development of oil shale, which began as early as the late 1800's. Oil and gas exploration has been active since the 1920's, including the Atomic Energy Commission's attempts to increase natural gas production by below-ground nuclear detonations.

Active interest in the development of oil shale resources was resumed in the early 1950's.

Cattle and sheep grazing have been the principal agents of vegetation change in the Piceance Basin in historic time. Related dominating agents include conversion of valley bottom communities to hay, and vegetation management practices, such as chaining, herbicide applications, and exotic species planting programs, all designed to increase the carrying capacity for cattle and sheep. As of 1970, livestock numbers in the Piceance Basin were approximately 10,000 cattle, 9,000 sheep, and 200 domestic horses (CER Geonuclear 1971). Under current federal protection laws, populations of feral horses are increasing rapidly in the region. At this time, only those areas physically inaccessible, under cultivation, or under development are free of grazing pressure from domestic livestock or feral horses.

Enormous cattle drives of the late 1800's probably had a profound effect on the vegetation in their pathways, and some local residents think it may have contributed to erosion of precious topsoil in some areas. The trail herd era ended near the turn of the century, precipitated by several very severe winters which reduced the herds substantially, and convinced cattle owners that a secondary source of feed was necessary. As a result, hay ranches were developed in the major valleys of the Piceance Basin, thereby converting native grasslands to hay meadows. Homesteads appeared simultaneously. Some attempts were made at dry-land farming by homesteaders but were terminated by the droughts of the 1930's, when the homesteaded lands reverted to range use, principally by sheep.

Recent factors contributing to localized changes in the basin's vegetative communities are roads, drill pads, exploration wells, and other surface disturbances associated with exploration for and development of energy resources. Recreational pressures for hunting, fishing, and camping are also increasing and creating local disturbances and dumps and increasing the changes of rangeland and woodland fires. Records maintained by the Colorado Division of Wildlife indicate that most fires in the Piceance Basin have been man-originated and of local extent. These fires have altered the composition and structure of the basin's vegetative communities very little compared to the changes prompted by vegetation management programs and grazing practices.

3.2.6 Natural Factors Affecting the Distribution of Piceance Basin Vegetation Resources

Vegetation development in the Piceance Basin is primarily affected by its relationship to the following factors: the overall climatic regime, elevational gradient, topographic aspect, animal impacts, geology, and soil development.

Aspects of the climatic regime of critical importance to Piceance Basin plants are: distribution and amounts of rainfall and snowfall, length of the growing season, maximum and minimum temperatures for a given area, and the frequency and velocity of wind. Rainfall in the region is low, producing semi-arid conditions; precipitation ranges from 200-400 mm per year. Approximately 75 percent of the precipitation is potentially evaporated. Precipitation as snow is particularly important to woody vegetation in late winter and early spring, and in general, supplies any moisture surplus occurring in soils for use during the growing season.

Available soil moisture is a major factor determining plant distributions. Shrub communities tend to occur on soils with the highest available moisture (i.e., lowest soil tension). Pinyon-juniper woodlands occur on shallow, well-drained soils that develop extremely high soil moisture deficits. Temperature and wind affect the water evaporation rate from soil, which affects moisture availability to plants. High temperature, principally the result of high surface heating, causes high rates of evaporation in most vegetation types at the lower end of the basin. Wind has the effect of increasing evaporative and trans-evaporative losses by increasing moisture deficits due to air movement away from "moist" surfaces. Length of growing season, and maximum and minimum temperatures, define limits within which plant species are physiologically tolerant and capable of reproduction. The region experiences extremes in both minimum and maximum temperatures. Mean values are -10°C and 45°C, respectively. Wind is also important in defining snowdrift patterns, which in turn, affect soil moisture. This is also true for vegetation structure; causing fallout and snow interception. An increase in elevation has the general effect of increasing precipitation, decreasing temperature, and decreasing soil pH (Daubenmire 1943), all from the general results of additional organic accumulations and the effects of leaching in soil.

Variations in topography affect the amount of sunlight striking different slopes. North-facing slopes tend to be cooler and wetter than other slope aspects, and south-facing slopes tend to be warmer and drier. East and west-facing slopes are intermediate in temperature and moisture, with east-facing slopes tending to be cooler and wetter than west-facing slopes. Because of these topographic modifications, plant communities characteristic of a lower, drier vegetation zone may be found on generally south-facing slopes in a high zone in the Piceance Basin, and plant communities from a higher, wetter zone may be found on the north-facing slope of a lower zone.

The geology of an area largely determines the types of soil that develop. Physical properties of soils determine aeration and moisture-holding capacity, and chemical properties are important in determining the availability of nutrients and water to plants.

Soils in this region generally have high pH values. This and other toxic soil properties cause interspecific action between soil constituents that produce inhibitory actions, and therefore, generally low nutrient regimes. Soil depth is important in determining moisture availability, in relationship with soil texture. This feature of soil determines the limits of the soil moisture control section, which in turn, influences moisture movements in soil as influenced by evaporative effects and leachings.

The recurring physiographic relief of the Piceance Basin combined with rather sharp discontinuities in adjacent soil types, especially along margins of drainages and the clearing pattern imposed by chaining, can create rather abrupt boundaries between adjacent plant communities. This characteristic of rather distinct community edges, rather than ecotonal or transitional boundaries, is illustrated particularly well in the Piceance Basin. An exception to this is the intergradation between alluvial and upland sagebrush types and between woodlands and shrublands.

3.2.7 Vegetation of Tract C-b Vicinity

The vegetation of the basin may be grouped into plant communities which are usually characterized by a particular life form and occupy a specific habitat.

Sixteen plant communities have been described for the Tract C-b study area and corridor (Keammerer 1975). Table 3-1 summarizes the dominant species found in each community.

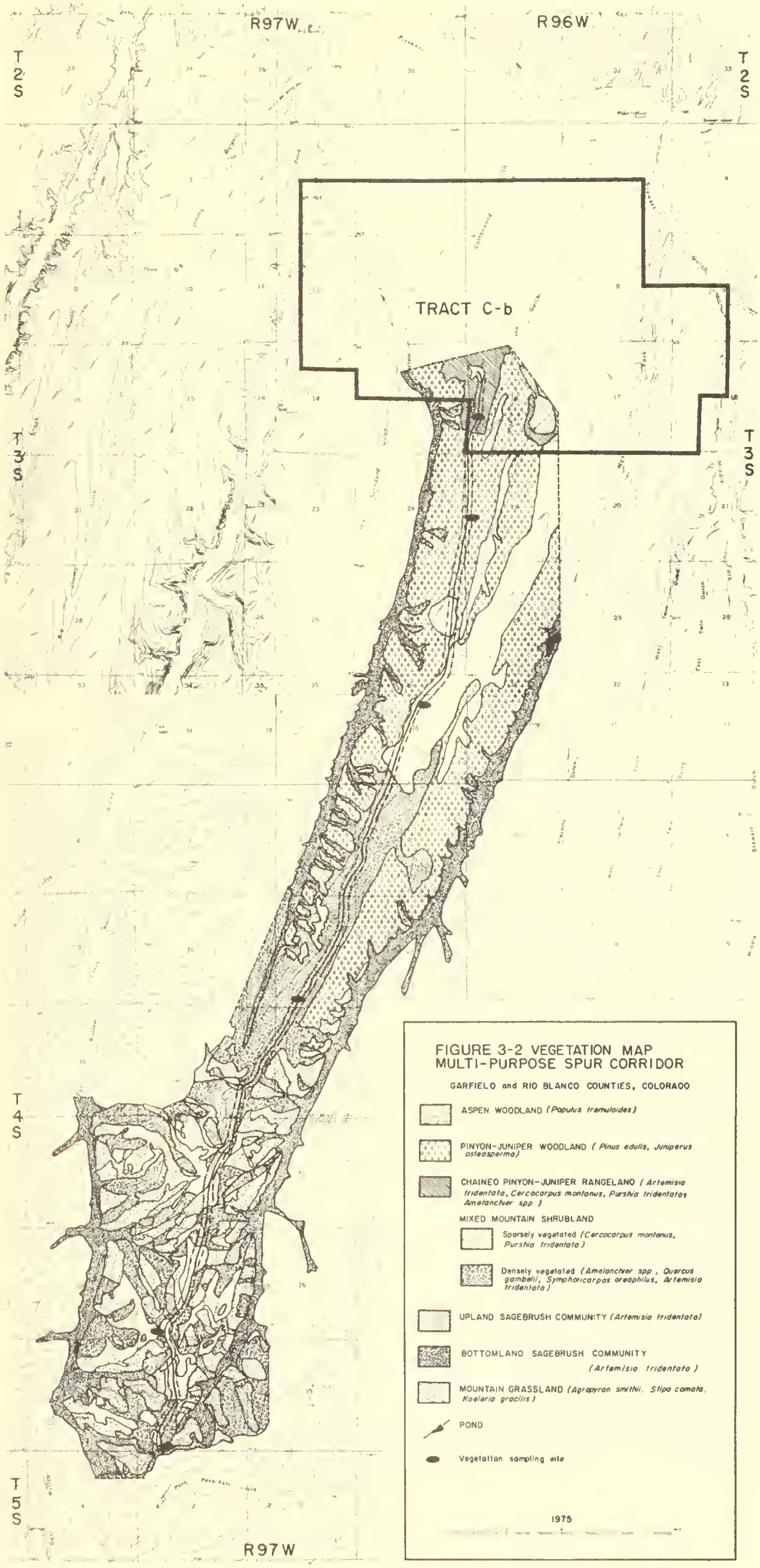
Chained pinyon-juniper comprises about 45 percent of the Tract, and is a result of range improvement activities initiated in 1966. The pinyon-juniper woodlands that remain are those restricted to the sides and bottoms of shallow draws and to ridgetops bounded by steeper valleys. Thus, the distribution of the Tract's plant communities and associated wildlife habitats has been markedly altered in a period of slightly more than one decade.

Aspen woodlands and mountain grasslands occur at the upper elevations of the basin and are not found on Tract C-b, but do occur in the multi-purpose corridor (Figure 3-2). The plant communities listed generally occur all through the basin. The overall vegetation mosaic may be more clearly viewed in terms of elevational zones containing these plant communities.

The plant communities lie within four broad vegetational zones of the western Rocky Mountains as described by Daubenmire (1943), Costello (1964), and Küchler (1964). These zones and the relationship of the plant communities to them are briefly summarized here.

Table 3-1 PLANT COMMUNITIES IN TRACT C-b AND VICINITY

Plant Community	Dominant Species
Aspen Woodlands	Aspen Chokecherry
Mountain Grasslands	Junegrass Western Wheatgrass
Pinyon-Juniper Woodland	Pinyon pine Utah juniper Rocky Mountain juniper
Chained Pinyon-Juniper Rangeland	Big sagebrush Mountain mahogany Antelope bitterbrush
Upland Sagebrush	Big sagebrush
Bottomland Sagebrush	Big sagebrush Winterfat Rubber rabbitbrush
Douglas-fir Forest	Douglas-fir
Mixed Mountain Shrubland	Gambel's oak Serviceberry Mountain mahogany Snowberry
Rabbitbrush	Rubber rabbitbrush
Greasewood	Black greasewood
Bunchgrass	Indian rice grass Blue-bunch wheat grass
Marshlands	Cattail Common reed
Riparian	Sedges
Agricultural Meadow	Alfalfa Timothy
Annual Weed	Russian thistle Cheatgrass
Great Basin Wild Rye	Great Basin wild rye


R97W
R96W
T 2 S
T 2 S
TRACT C-b
T 3 S
T 3 S
T 4 S
T 5 S
R97W
FIGURE 3-2 VEGETATION MAP
MULTI-PURPOSE SPUR CORRIDOR
GARFIELD and RIO BLANCO COUNTIES, COLORADO
ASPEN WOODLAND (Populus tremuloides)
PINYON-JUNIPER WOODLAND (Pinus edulis, Juniperus osteosperma)
CHAINED PINYON-JUNIPER RANGELAND (Artemisia tridentata, Cercocarpus montanus, Purshia tridentata, Amelanchier spp)
MIXED MOUNTAIN SHRUBLAND
Sparsely vegetated (Cercocarpus montanus, Purshia tridentata)
Densely vegetated (Amelanchier spp, Quercus gambelii, Symphoricarpos oreophilus, Artemisia tridentata)
UPLAND SAGEBRUSH COMMUNITY (Artemisia tridentata)
BOTTOMLAND SAGEBRUSH COMMUNITY (Artemisia tridentata)
MOUNTAIN GRASSLAND (Agropyron smithii, Stipa comata, Koeleria gracilis)
POND
Vegetation sampling site
1975

3.2.7.1 Low Elevation Desert Shrub Zone

At lower elevations of the Piceance Basin and Tract C-b, the bottomland sagebrush, bunchgrass, greasewood, Great Basin wild rye, rabbitbrush, marshland, riparian, annual weed, and agricultural meadow communities occur.

Bottomland sagebrush communities typically dominate the valley floors and alluvial fans of the gulches throughout the basin. The larger valleys containing intermittent streams usually support this vegetation type. Stands of sagebrush occur at the mouths of most of the small gulches that feed into the major drainages. Narrow strips of sagebrush communities also extend along the intermittent stream channels into small draws. Within the Tract study area, the most fully developed stands of bottomland sagebrush exist in Scandard Gulch and along West Fork Stewart Creek. Rabbitbrush communities in the Piceance Basin are generally restricted to floodplain areas that previously supported big sagebrush. Sites supporting rabbitbrush communities appear to have been disturbed in some manner since early settlement times. On Tract C-b, the best development of rabbitbrush occurs at the mouth of West Fork Stewart Gulch. Other small stands of rabbitbrush occur at various locations within the Stewart Creek drainage and in the upper portions of Willow Creek valley.

Throughout the basin, semi-aquatic species grow in narrow bands along the permanent streams and occur as dominant species in the riparian community. Since there is no permanent stream flow within the Tract, no riparian vegetation occurs within the Tract proper, but it does occur near the Tract along Piceance Creek, Willow Creek, and bordering the lower portions of Stewart Creek. Along the floodplains of major streams, stands of sagebrush have been removed and the ground converted to agricultural meadows composed primarily of alfalfa and introduced pasture grasses. These meadows are used primarily for hay production and as pasturage. Hay meadows are common along Piceance Creek and Willow Creek in the Tract vicinity. The annual weed vegetation type occurs in areas where sagebrush has been eliminated and livestock disturbance is fairly continual; it also develops along access roads and in areas disturbed by drill pads.

The bunchgrass community occurs primarily on steep talus slopes rising above the basin's major valleys. This community occupies an intermediate elevational position between pinyon-juniper woodlands and the bottomland sagebrush. The bunchgrass type also occurs on burned pinyon-juniper sites on the Tract.

Several authors have suggested that Great Basin wild rye was much more extensive in the Piceance Basin before settlement than it is at present (Personal Communication, SCS, Meeker). Currently, this community forms small, dense stands at the heads of drainages immediately above the bottomland sagebrush type.

Other remnants occur along areas of Piceance Creek, suggesting that this community was fairly widely distributed on floodplains prior to their development for agriculture. On the Tract area, stands of Great Basin wild rye are restricted to small floodplain areas along Willow Creek and East Fork of Stewart Gulch.

The greasewood community occupies saline alluvial deposits throughout the Basin. It is common along Piceance Creek, north of Tract C-b. Small isolated stands of black greasewood occur on highly saline-sodic or alkaline soils on the Tract and throughout lower elevations of the Piceance Basin. Black greasewood is tolerant of salts, is a phreatophyte, and has a long root which taps the ground water found in the alluvium. When greasewood is removed or badly disturbed, it is either replaced by annual weeds or by rubber rabbitbrush.

The marshland community is relatively uncommon in the Piceance Basin owing to the limited distribution of permanent water. Several small marshes occur within the Tract study area but none are within Tract C-b proper. Fairly extensive marshes have developed along Piceance Creek, where they either occurred as part of the original vegetation or have been produced through the ponding of overland flow irrigation waters.

3.2.7.2 Mid Elevation Pinyon-Juniper Zone

The most extensive plant community within the Piceance Basin is dominated by pinyon pine and Utah juniper. This type occupies the same elevational range as the upland sagebrush type (Vories 1974). Sagebrush tends to grow in the valleys, on mesas, or on gentle slopes possessing fine deep soils, while the pinyon-juniper woodland occupies ridges, canyons, or rough slopes characterized by coarse, rocky, or shallow soils. On slopes where snow accumulates in the winter, mixed mountain shrub communities dominate. Pinyon-juniper is found on well-drained slopes and on slopes where snow does not accumulate.

On Tract C-b, pinyon-juniper stands occur primarily on ridges and dry slopes. This type is generally absent from alluvial deposits, talus slopes, and from loamy upland soils. Until recently, these woodlands covered most of the Tract; during 1966, the Bureau of Land Management chaining operations removed approximately 2500 acres of pinyon-juniper woodlands within the Tract boundaries. Even though the total extent of the woodlands was reduced by more than 50 percent, it remains as one of the most common vegetation types on the Tract and is an especially important wildlife habitat.

The chained rangelands constitute a highly variable and somewhat artificial plant community. Chaining was primarily restricted

to ridges and gentle hillsides where operation of bulldozers was feasible. On the Tract, the chained rangelands occur primarily in the central portion of the study area and cover approximately 45 percent of the Tract's area.

At higher elevations the oak-mountain mahogany plant community intergrades with upland sagebrush and mixed mountain shrub communities. Both are well distributed in the Piceance Basin. The upland sagebrush type is located on the more mesic ridgetops at mid-and-higher elevations in the Piceance Basin. Utah serviceberry, rabbitbrush, and snowberry are often associated with upland sagebrush communities. The shrub and herbaceous strata of this vegetation type are the most compositionally diverse of any type in the immediate Tract area, suggesting a relatively favorable microenvironment. Within the Tract study area, upland sagebrush occurs on broad ridgetops and in clearings within the pinyon-juniper woodland.

The mixed mountain shrub type in the Piceance Basin is comprised of a number of shrub species. Gambel's oak, Utah serviceberry, and mountain mahogany are the most common. At any location, the type may either occur as a relatively pure stand of a single shrub species, or it may support a number of shrub species. In these instances, the shrub community may exhibit a multilayered appearance owing to the presence of smaller shrubs in the understory. (Several shrub species may occur as dominants or co-dominants, but the structure and composition of this type varies considerably depending upon slope, exposure, edaphic conditions, moisture conditions, and human disturbance). The most diverse stands of the mixed shrub type tend to be located on steep north or east-facing slopes, usually at intermediate elevations. These sites are typically more exposed than either Aspen or Douglas-fir types. The mixed mountain shrub type on the Tract study area is very limited in distribution, and occurs principally on north-facing slopes toward the southern and southwestern edges of the Tract.

3.2.7.3 Upper Elevation Douglas-fir Zone

Stands of Douglas-fir exist over a wide elevational range in the Piceance Basin and are present in a few locations in the Tract C-b area. This community type is most frequently found at higher elevations of the Basin, most commonly on north to northwest-facing slopes. Stands that have colonized steep canyon walls at lower elevations or on south-facing slopes demonstrate little, if any, reproductive success. Aspen stands often border Douglas-fir forests, and in areas where stands were growing in relatively dry situations have been logged or burned, Aspen woodlands form the pioneer vegetation. Mixed stands of both Aspen and Douglas-fir occur, but Douglas-fir usually dominates on north-facing slopes, being better adapted for these cool, moist sites. Mountain grasslands appear as balds on hilltops and exposed ridges at higher elevations.

3.2.8 Summary

In summary, the principal vegetation types found on Tract C-b are distributed over much of the Piceance Basin. None are unusual in species composition or structure. All have been subjected to the influences and disturbances related to livestock grazing, cultivation, mechanical range improvement, or other human activities. On the Tract proper, extensive chaining of pinyon-juniper woodlands has markedly modified the natural distribution and pattern of the original woodland communities.

3.3 Wildlife

3.3.1 Introduction

Wildlife species are usually distributed according to the vegetation cover, topographic relief, and elevation. In northwestern Colorado and the Piceance Basin the great diversity of vegetation types and the interspersion of ridges, valleys, and cliffs provide a wide variety of habitats for wildlife. Habitat types are landscape units analogous to vegetation types, except that they include physical features important to wildlife, such as open water, rimrock, exposed slopes, and spatial arrangement of vegetation (Pocket Figure 3-3 refer to pocket, inside back cover).

In total about 55 mammal species, more than 160 bird species, 6 amphibian species, and 17 reptile species are anticipated to occur in the varied habitats of the Piceance Basin. Within the Tract C-b study area, 32 species of mammals, 136 of birds, 2 of amphibians, and 5 of reptiles were documented during baseline investigations.

Pinyon-juniper woodland, the typical habitat type of the region, is replaced by other types, such as sagebrush, mixed shrublands, marshlands, and aspen groves, at higher elevations or on moist sites. A variety of animal species inhabit the pinyon-juniper habitat type, but surprisingly few species are totally dependent on the resources of the pinyon-juniper habitat for their survival (Frischknecht 1975). A small mammal that may be considered dependent on the pinyon-juniper ecosystem of the Piceance Basin is the pinyon mouse; a few bird species, such as the pinyon jay and the titmouse, also rely on the area's pinyon-juniper communities. They depend on the food provided by the pinyon nuts and juniper berries and on cover afforded by the tree stratum and associated deadfalls. Seed dispersal by birds and mammals is probably an important faunal-vegetation relationship that insures the survival of both.

Mule deer are clearly the dominant wildlife species and the most economically important game species inhabiting the Piceance Basin. They thrive here in large numbers and can dramatically influence the range they inhabit. The interspersed plant communities (Sec. 3.2) characteristic of the Basin offer ideal mule deer habitat. Ideal habitat has much edge effect, having tree stands interspersed with open areas of shrubs. Mule deer find protection from the harsh winters in the dense and well-protected pinyon-juniper stands, while various shrub types, also widespread in the Piceance Basin, offer ample high quality browse the year round.

In autumn the deer migrate from higher elevations to the lower Piceance Creek meadows and the Tract C-b ridges and valleys.

A number of mammalian and avian predators, notably coyotes, bobcats, badgers, weasels, hawks, owls, and eagles, range throughout the Piceance Basin and assist in the control of populations of their major prey species, primarily small mammals and birds. The coyote is probably the most important predatory animal inhabiting the Piceance Basin.

Birds of the region are distributed according to the habitat types available. Most of the Basin's recorded birds have also been sighted on Tract C-b.

Reptiles and amphibians are not abundant in the vicinity and are represented by only seven species, probably due to lack of suitable habitat.

3.3.2 Historical Records

The earliest written records of wildlife occurrence in northwestern Colorado are in the writings of two naturalists who traveled the area (Cary 1911, Warren 1942). They based their interpretations of the then existing biological setting on field collections, observations, and on the reports of local ranchers, trappers, and miners. Unfortunately, both naturalists arrived on the scene too late to describe presettlement conditions; at the time of their reconnaissance, some 30 years of intensive human activity had already occurred. Nonetheless, their accounts suggest that rather dramatic declines in deer, elk, antelope, bison, wolf, and mountain lion had occurred. The writings of Cary (1911) included some interesting facts about buffalo and wolves, now absent, and about mountain lions, now making a comeback in the basin. The last buffalo in Routt County had been killed by the Ute Indians near Craig in 1884. Reports indicated wolves were not scarce:

> "Wolves are still found in considerable numbers in Routt and Rio Blanco Counties, where they kill a great many range cattle. In 1905, wolves were reported in considerable numbers in the White River country, particularly in the valley of the Piceance..."

Mountain lions, according to the 1911 report, were eliminated from the Meeker region by trapping and poisoning. The Colorado Division of Wildlife presently reports a number of mountain lions, mainly on the Roan Plateau, and permits limited hunting in the area. At least four mountain lions were shot in 1976 near Little Hills Experiment Station (personal communication). Despite the literature being replete with anecdotes telling of the herds of game in "the early days," almost nothing factual is known about wildlife

populations in the Piceance Basin except through the years there has been a history of unrestricted harvesting of deer and alteration of wildlife habitats by livestock interests. Recollections by Meeker historians have reported that bottomlands in the Piceance Basin had extensive tall grass. The legendary "tall grass" was so high, a man on horseback could not be seen (from "This Is How I Remember It," Meeker Historical Society).

Until recently, very few efforts have been undertaken to describe the ecology of northwestern Colorado, and the Piceance Basin in particular. Establishment of the Colorado Division of Wildlife's Little Hills Wildlife Experiment Station was the first attempt to gather long-term data on selected components of the terrestrial ecosystem, emphasizing mule deer. Recent studies sponsored by the U.S. Fish and Wildlife Service, under the direction of Dr. Robert Finley, have complied data regarding small mammal distribution and ecology in the Piceance Basin. By far, the most comprehensive ecosystem studies (i.e., studies that consider a large number of ecosystem components rather than focusing on one or two components) have been undertaken in response to the Federal Oil Shale Lease Stipulations, which require that those seeking to develop oil shale Tracts C-a and C-b first must describe in some detail, the ecological resources of these leaseholds. Thus, trend data on most wildlife populations of the Piceance Basin are not available, and data reported in Volume IV of this final report represent the first compliation and evaluation of wildlife resource information for the Tract C-b vicinity.

3.3.3 Factors Affecting Wildlife Distribution in the Piceance Basin

The diversity of Piceance Basin vegetation types and topographic relief provides a wide variety of habitat situations for wildlife species. With few exceptions, Piceance Basin wildlife tends to be distributed relative to the vegetation types, upon which wildlife species depend, and also upon elevation. Small mammals, reptiles, and songbirds are usually closely associated with a given vegetation type at a given elevation, either because of their limited mobility or specific food and cover requirements. Conversely, large mammals and large birds (e.g., mule deer, coyotes, badgers, bobcats, and raptors) are more mobile and, therefore, can utilize a large number of vegetation types at virtually all elevations.

Predators, for example, must cover large areas in pursuit of prey, while large ungulates such as mule deer are stimulated to move along elevational gradients by changes in snow depth, weather factors, and forage availability.

Because of the relatively small size of the Piceance Basin, wildlife species inhabiting one portion of the Basin, such as those identified on Federal Oil Shale Tracts C-a and C-b, can generally be found in similar habitat types throughout the Basin. That is, important species of the Piceance Basin wildlife usually occur in all appropriate habitats. Elevational differences within the Basin and within the Tract C-b study area probably impose the greatest limitations on wildlife distribution.

Studies conducted on the two Federal Oil Shale Tracts in the Basin revealed that certain small mammal and bird species which occur in abundance at lower elevations are not encountered at higher elevations within the same vegetation types. Moreover, a few wildlife species are generally found only at higher elevations in the Basin, despite vegetation types upon which they depend being well distributed at lower elevations. This is evident from comparing mammal lists of Tract C-b (refer to Appendix Volume IV, Table B-4-2) and the higher elevation corridor (refer to Appendix, Volume I, Table A-2). These two studies provide an elevational transect from the bottomlands of Piceance Creek (6200') to the Roan Plateau (8500').

There are few differences in species composition between Tract C-b and the surrounding areas. At higher elevations, Gapper's red-backed vole lives in Aspen habitat (8300') but was not identified on Tract C-b, which lacks Aspen habitat. Horned larks occur in wide open areas also at the higher elevations. Several other mammals were documented only for the higher elevations: thirteen-lined ground squirrel in mixed mountain shrub and grassland habitat between 8000 and 8500 feet; and elk in mixed mountain shrub habitat at approximately 8500 feet.

Mule deer and many predatory animals move from higher to lower elevations in response to environmental conditions that generally determine the availability of suitable forage or prey. From studies of deer over the Tract C-b area and the corridor to the south, winter range occurs at the lower elevations and summer range at the higher elevations. Winter and summer deer ranges overlap in the locale between 7500 and 7800 feet on ridgetops and around 6500 feet in valleys where deep snow accumulates (see Figure 3-4).

Bird habitats are distributed according to food sources and nesting sites. Many raptors select cliff faces for nests, and mourning doves choose shrublands in lower valleys. Sage grouse require higher elevation sagebrush stands for nesting.

Food availability becomes a problem in wintertime. Many birds migrate south to avoid the winters, while others can survive the winter in protective vegetation and join other birds in mixed flocks to seek food.

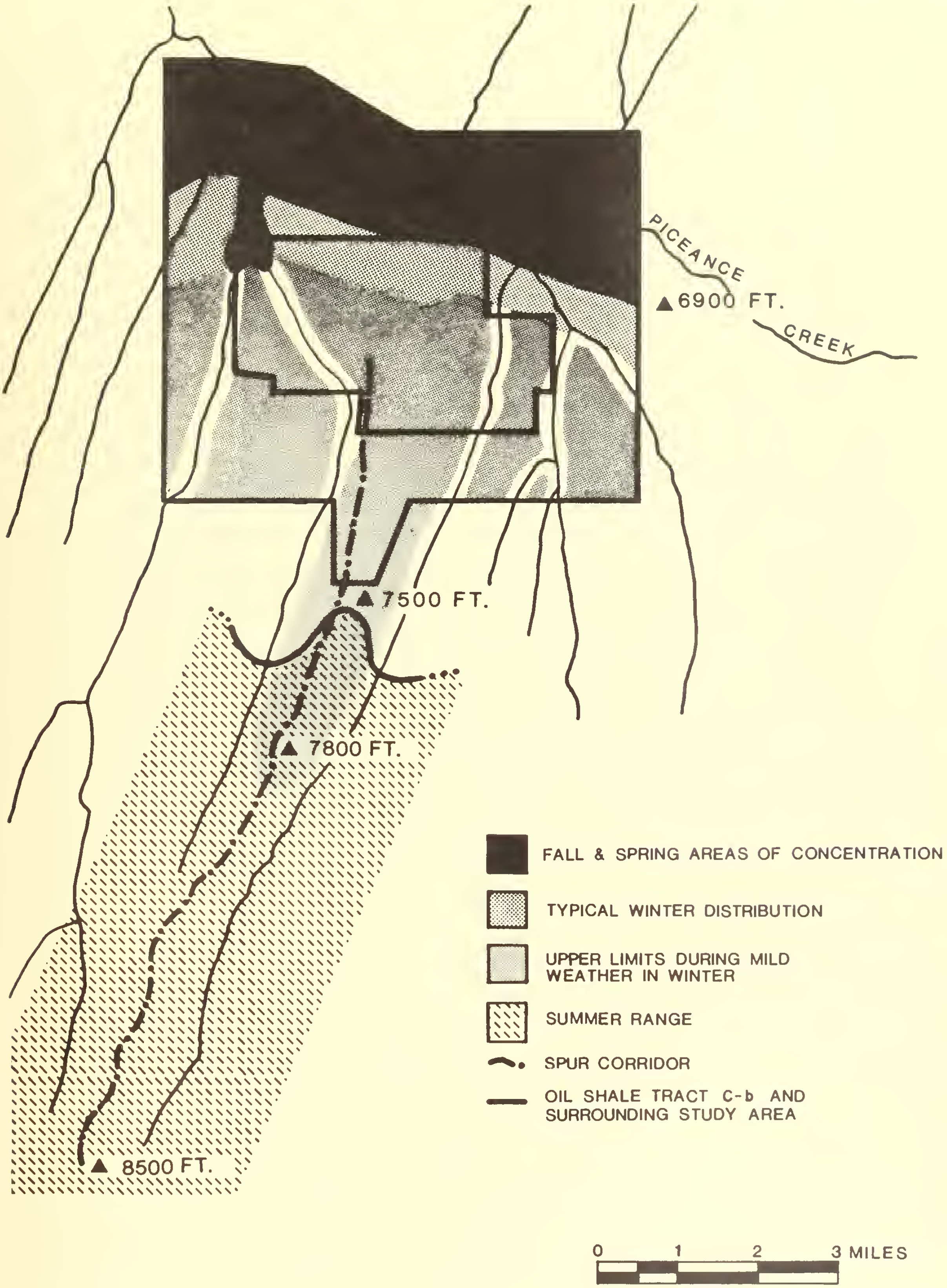


FIGURE 3-4 WINTER AND SUMMER RANGES OF MULE DEER ALONG THE SPUR CORRIDOR AND TRACT C-b

Some birds commonly found in mixed winter flocks in the basin are mountain chickadees and dark-eyed and gray-headed juncos. Large flocks of Bohemian waxwings may sporadically winter in this area, at the eastern edge of its distribution, possibly following food supply.

In addition to the 136 bird species observed within the study area, there have been sightings of 25 additional species in other portions of the Piceance Basin; the following are a few of these 25: chukar partridge, great blue heron, Swainson's hawk, peregrin falcon, merlin, blue grouse, semipalmated plover, bushtit, and redhead.

Collections of reptiles and amphibians in the region are not complete enough to give an accurate picture of distributions and numbers. Seven species were identified during Tract C-b baseline studies: Utah tiger salamander, leopard frog, four common lizard species, and western garter snake. The Parachute Creek valley has, in addition to these, the collared lizard, side-blotched lizard, plateau whiptail, western rattlesnake, racer, gopher snake, great basin spadefoot, and Woodhouse's toad.

3.3.4 Habitat Types and Characteristic Wildlife of the Piceance Basin and Tract C-b Vicinity

During the past two years, many terrestrial and aquatic wildlife species have been studied in detail in the Piceance Basin, with most studies concentrated on the Federal Lease Tracts. The results of studies conducted on Tract C-b, as detailed in Volume IV, make numerous references to habitat types (Pocket Figure 3-3) which are the structural or spatial components within which the present-day wildlife setting is most appropriately placed.

Habitat types are landscape units arbitrarily defined for the purpose of conveniently describing animal assemblages, seasonal movement patterns, and feeding areas. The concept of the habitat type is analogous in rationale to the vegetative type. As used here, habitat type differs from vegetative type mainly in that physical features important to wildlife are also included. For example, open water, rimrock, south-facing slopes, and low and high elevations are likely to be as important in the influence of animal distribution as are the composition and structure of plant communities.

The varied topography, soil, moisture conditions, and man-induced modifications of the Piceance Basin and the Tract C-b study area have created a diversity of habitat for fauna. The pinyon-juniper vegetation type in the Piceance Basin and in the Tract C-b vicinity, for example, varies from sparsely distributed, stunted trees interspersed by bunchgrass communities on steep, dry, south-facing slopes and rock cliff areas, to dense tree stands having high

canopy cover on more moist, north-facing slopes. Throughout its range in the Piceance Basin, the pinyon-juniper vegetation type is interrupted by stands of big sagebrush, both on relatively level upland sites and in alluvial bottoms, and by the mixed mountain shrub vegetation type at higher elevations where precipitation is greater. Man-induced disturbance in the Piceance Basin, and in the Tract C-b study area in particular, has removed large acreages of pinyon and juniper trees resulting in expansive open areas dominated by shrubs and herbaceous vegetation characteristic of Piceance Basin pinyon-juniper understory. Rabbitbrush has invaded some bottomland areas where sagebrush has been removed. The resultant mosaic of plant communities provides a considerable variety of habitat types available to resident fauna.

The classification of habitat types as presented in Table 3-2 has two main objectives. The first is to facilitate discussions of animal ecology as they relate specifically to Tract C-b; the second is to permit comparisons to be made of Tract-specific data with conditions elsewhere in the region. Six major units, consisting of 19 wildlife habitat types, have been recognized. This categorizes what is currently known regarding wildlife distributions through habitat types in the region. Table A-1 (refer to Appendix) compares these habitat types with the BLM habitat units. The major habitat types follow roughly an elevational gradient from the lowland streams to the ridgetop pinyon-juniper and higher elevation mountain forests. Information from Tract C-b studies and the adjacent corridor to the south (Figure 3-5) provided a transect across the elevational gradient from the bottom of the Piceance Basin to the upper edge in the southeastern part of the Basin. An elevation of 6500 feet is a convenient point on this gradient and was frequently observed as the limit to many avian and mammalian species distributions. It also approximates the upper reaches of deer winter range in the valleys.

3.3.4.1 Open Water

The general paucity of open water in the Piceance Basin as a whole contributes to small concentrations of waterfowl in the few areas such as Piceance Creek and adjacent small ponds, where open water is available. Rio Blanco Lake, a manmade diversion, on the White River near its confluence with Piceance Creek, is the largest single open water body around the Basin. The Piceance Basin is not recognized as a segment of any major waterfowl migratory route within the Pacific Flyway. Small migratory flocks of waterfowl such as Canadian geese do use open water in and around the Basin. Large perennial streams such as Piceance and Yellow Creeks may have open water year round. The presence of open water near Tract C-b accounts for the presence of waterfowl, shorebirds, muskrats, and occasionally beaver that would otherwise not occur.

Table 3-2 HABITAT AFFINITIES OF MAMMALS IN THE SOUTHEASTERN QUARTER OF THE PICEANCE BASIN

Mammals	RIPARIAN AREAS			LOWER VALLEYS (below 6500 ft.)				UPPER VALLEYS (above 6500 ft.)				PINYON-JUNIPER			UPLAND SHRUB & GRASSLAND			MOUNTAI FOREST	
	Open Water	Riparian vegetation	Cotton-wood grove	Agricul-tural meadow	Bunchgrass Communities	Bottomland sagebrush	Lateral draws	Agricul-tural meadow	Bunchgrass Communities	Bottomland sagebrush	Rimrock	Pinyon-juniper woodland	Burned areas	Chained pinyon-juniper rangeland	Upland sagebrush	Mixed mountain shrubland	Mountain grass-land	Douglas-fir forest	[illegible] wood-lan
Wandering shrew																			●
Desert cottontail		●		●								●				●	●		
White-tailed jackrabbit				●												●	●		
Apache pocket mouse					●				●			o		o	o				
Beaver	●	●	●																
Bushy-tailed woodrat		●			●	●					●	●		o					
Canyon mouse**					●				o										
Chickaree																		●	
Deer mouse		●		o	o	o		o	●	o	o	●		o	●	●	●		
Gapper's red-backed vole																			●
Golden-mantled ground squirrel					●	●	●		●	●	●	●		●	●	●	●		
House mouse**		●		●															
Long-tailed vole									●										●
Least chipmunk					●	o									●	●			●
Montane vole		●		●															
Muskrat	●	●																	
Northern pocket gopher				●		●	●	o	●	●			●			●			●
Porcupine												●				●		●	
Richardson's ground squirrel				o				●											
Rock squirrel**				●	●	●													
Sagebrush vole														o	●				
Thirteen-lined ground squirrel																●	●		
White-tailed prairie dog				●															
Yellow-bellied marmot		●		●	●														
Badger				●	●														
Bobcat									●	●	●	●							
Coyote		●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●		
Ermine														o		●			
Gray fox		●																	
Long-tailed weasel		●																	
Raccoon	●	●	●	●				●											
Striped skunk		●		●															
American elk							●					●	●		●	●	●		
Mule deer		●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●

(Lines represent the usual or characteristic habitat. Dots and circles represent documented occurrences.*)

* ● species documented in the Piceance Basin region (Stoecker-Keammerer & Assoc.)

o species documented in the Tract C-b study area (Woodward-Clyde, Inc.)

** Identified only in the Colorado River drainage.

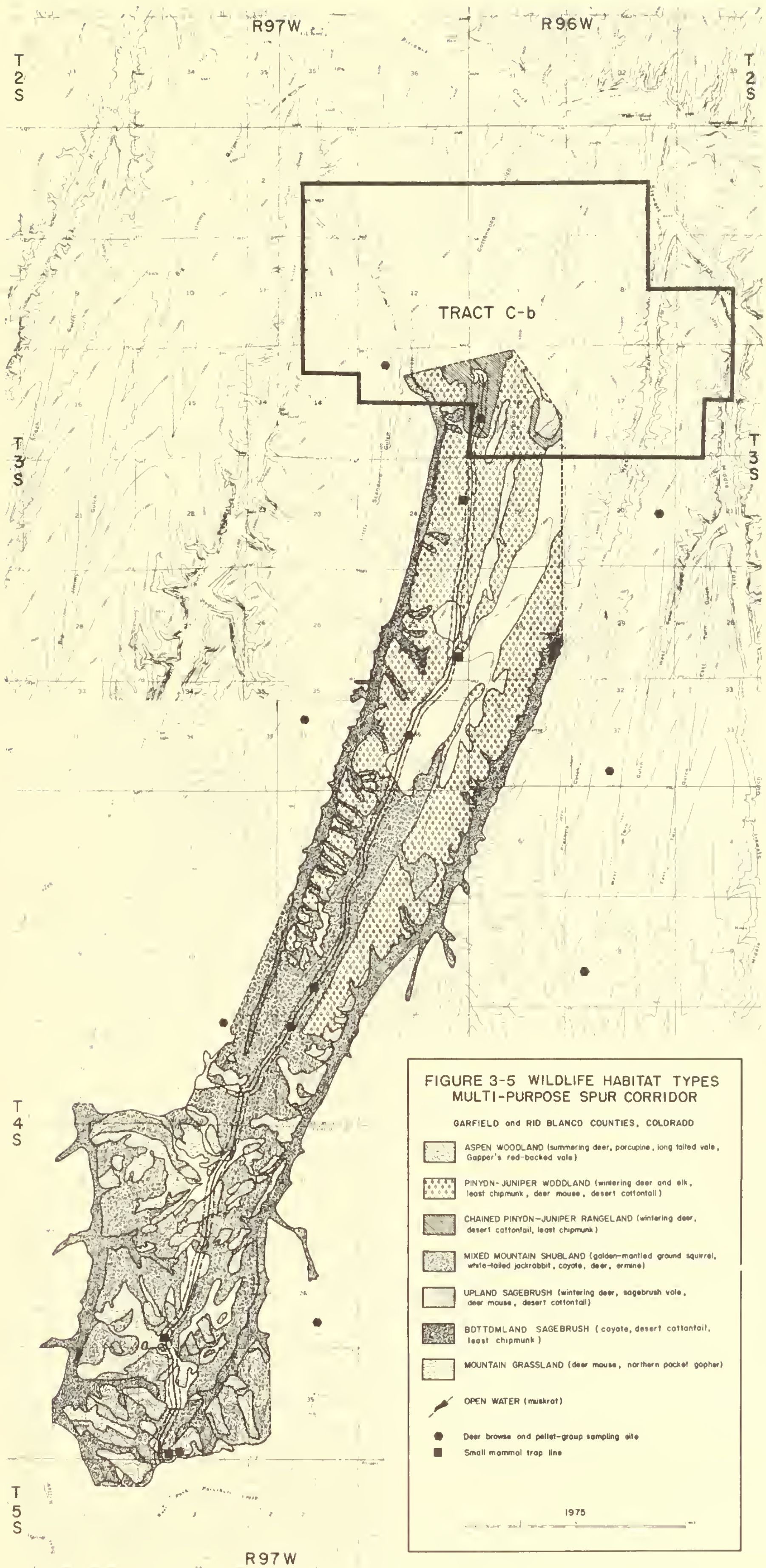


FIGURE 3-5 WILDLIFE HABITAT TYPES MULTI-PURPOSE SPUR CORRIDOR

3.3.4.2 Riparian Areas

The unique feature of a riparian habitat is the moist condition that prevails. Riparian vegetation grows on stream banks at the water's edge. In a semi-arid region such as the Piceance Basin, areas where moisture is retained are of considerable importance to wildlife. Since they are in short supply regionally, riparian areas tend to become oases for wildlife species dependent on these moist conditions atypical of the region. This limited riparian habitat is somewhat attractive to greater sandhill cranes during their migratory period.

In the basin and on Tract C-b, riparian vegetation is associated with small springs and seeps which may or may not support open water. Cottonwood groves occur as discontinuous islands in moist stream bottoms. The only sighting of a red-eyed vireo in the C-b study area occurred within the only cottonwood stand. Marshes and stream-side vegetation attract and support various shorebirds and a number of small and large mammals seeking moisture.

3.3.4.3 Agricultural Meadows

The term "agricultural meadows" is restricted to locations that have been physically modified through cultivation and other agricultural activities. In the Piceance Basin, these areas include bottom-lands that are used as hay meadows or pastures. Some meadows and pastures in the basin may have been formed by removal of bottomland sagebrush stands through clearing or herbicide application. Areas surrounding Piceance Creek, Stewart Creek, and Willow Creek in the area of Tract C-b support pastures and hay meadows. These are important habitats for the montane vole, an important prey species in the Piceance Basin; moreover, the meadows provide food for mule deer during fall and spring. Hawks and owls depend on these open meadows for hunting and capturing prey.

3.3.4.4 Bunchgrass Communities

Lower slopes and bunchgrass areas are frequently vegetated by Indian ricegrass and scattered pinyons and junipers. The south facing slopes are especially important to deer during times of deep snow, as the sun often melts off snow cover on south-facing slopes.

Bunchgrass communities may eventually develop in some disturbed sites. Early succession shows annual weed communities occur in valley disturbed sites. Russian-thistle, lambsquarters, pigweed, cheatgrass, or other characteristic annual plants that grow in disturbed sites are often referred to as "invader" species. Disturbed sites in the Piceance Basin and in the Tract C-b area may include old roadways, building sites, or drillpads. They attract birds

and mammals that favor seeds for food and can temporarily support large flocks of wintering finches and sparrows. Chipmunks and other small rodents are often numerous in disturbed areas because burrowing is favored by the loose soil and food is abundant.

At higher elevations, mountain grasslands have a limited distribution. Typically, they occur on convex slopes and are composed largely of needle-and-thread grass, western wheatgrass and Junegrass. Deer mice and northern pocket gophers are most frequently found here.

3.3.4.5 Bottomland Sagebrush

Bottomland shrubs are mainly greasewood, rabbitbrush, and big sagebrush. While recognized as distinct plant communities, they are combined into the same category because they provide a relatively uniform habitat type for wildlife. Bottomland sagebrush and rabbitbrush provide good habitat for desert cottontails and often support large populations of small mammals such as mice and chipmunks. Birds typically found in bottomland sagebrush here are the house wren, violet-green swallow, tree sparrow, song sparrow, robin, and northern shrike. Scrub jays winter in this habitat type.

3.3.4.6 Lateral Draws

Bottomland sagebrush extends from the alluvial fans into lateral draws. The lateral draws have a particular significance to deer, providing both food and cover during periods of severe winter weather. Lateral draws are small, steep valleys which occur as side drainages, perpendicular to their major valleys. In the Piceance Basin, they are characterized by a steep, intermittent drainage channel that intersects the bedrock at the head of the draw and forms a steep-sided channel through the alluvium at the mouth of the draw. Besides sagebrush on the alluvial fans, mixed mountain shrubs, typically bitterbrush, mountain mahogany, serviceberry, and occasionally Gambel's oak occur on northern exposures and bunchgrasses with scattered pinyon pine and juniper occurring on the southern exposures.

3.3.4.7 Upland Sagebrush

Upland sagebrush refers to the extensive stands of big sagebrush that occur as clearing within or near pinyon-juniper woodland on ridgetops and frequently at higher elevations. Some mammals commonly expected in the upland sagebrush habitat are: wintering deer, sagebrush vole, deer mouse, desert cottontail, and least chipmunk.

Upland sagebrush is less distinct and homogeneous than bottomland sagebrush. It intergrades with pinyon-juniper and in these

areas could be labeled "upland transition" because it tends to have a distinct bird population, e.g., Virginia's warbler, orange-crowned warbler, and brewer's sparrow. The upland sagebrush habitat is easily delimited when it occurs as a clearing within a pinyon-juniper woodland. It is relatively low in stature, individuals are scattered, and it is heavily used by wintering deer for browse. In contrast, bottomland sagebrush is often six to eight feet tall, rather dense and homogeneous, and seldom utilized by deer.

3.3.4.8 Mixed Mountain Shrublands

Mixed mountain shrublands consist primarily of mountain mahogany, serviceberry, bitterbrush, Gambel's oak, and big sagebrush. This habitat type is significant to mule deer for food, and has an extensive distribution at higher elevations to the south of Tract C-b. Within the Tract C-b study area, it is of limited occurrence and usually occupies north-facing slopes. Mammalian inhabitants in these areas include golden-mantled ground squirrel, white-tailed jackrabbit, coyote, deer, and ermine. Birds usually encountered here are green-tailed towhee, vesper sparrow, and broad-tailed hummingbird. Feeding flocks of numerous individuals frequent the mixed mountain shrubland in fall and winter. The fall flocks consist of black-capped chickadees, mountain chickadees, and the ruby-crowned kinglet. In winter the mountain chickadee is joined by dark-eyed and gray-headed juncos.

3.3.4.9 Pinyon-Juniper Habitats

The pinyon-juniper woodlands in the Piceance Basin are the most prevalent habitat type, intergrading with upland shrubs and grasslands. Rimrock occurs in close proximity to pinyon-juniper woodlands and provides important densities and nesting areas for both birds and mammals. It consists of sandstone cliffs and ledges flanking many of the valleys throughout the basin and is particularly well-developed in and near the Tract C-b study area. The most common inhabitants of rimrock are raptors, the red-tailed hawk, the great horned owl, kestrel, and the golden eagle. Although these birds may nest alternately in trees, they prefer the rock outcroppings as nest sites. Pinyon-juniper woodlands are widespread over the Piceance Basin occurring over a wide elevational range. Understory vegetation varies considerably with some stands supporting a dense shrub and grass understory and others being more open and sparsely vegetated. The pinyon-juniper woodlands frequently intergrade with sagebrush and mixed mountain shrub communities forming communities dominated by pinyon and juniper, but supporting a fairly dense shrub stratum. In cases where the pinyon-juniper type integrades with the mixed mountain shrub vegetation type, the understory may be quite diverse, consisting of

several different shrub species and numerous herbaceous species. Areas such as these are important to wintering mule deer in that the usually dense tree stratum provides needed cover and protection from harsh winter conditions, while the diverse shrub understory provides ample browse.

Several herbivorous small mammal species (e.g., piñon mouse, Uinta chipmunk, and bushy-tailed woodrat) and some birds, are mostly restricted to pinyon-juniper vegetation type in the C-b study area, and appear to be associated with the pinyon-juniper vegetation type as a result of their food and nesting requirements. Piñon mice, pinyon jays, and Uinta chipmunks depend directly on pinyon and juniper for both food and nesting material. Woodrats nest in juniper stumps and in the many rock outcrops prevalent in this vegetation type, depending heavily on pinyon nuts and juniper berries as a food source.

Frischknecht (1975) stated that seed disperal by birds and mammals is perhaps the most important mutualistic effect of pinyon-juniper faunal/vegetation relationships. This probably is also true for the sagebrush communities. Both juniper and pinyon seeds, for example, can be carried long distances from their source in the cheek pouches of small mammals, such as chipmunks, or in the feces of animals, such as cottontail rabbits and pinyon jays. It has been speculated that some seeds passed by animals germinate more readily than others, and also that some seeds remain viable for longer periods of time after passing through the digestive systems of certain animals (Johnson 1962). Parker (1945) attributed invasion of certain grassland areas by juniper to distribution of seeds by animals.

Birds most often encountered in pinyon-juniper habitats are: black-throated gray warbler, Townsend's solitaire, pinyon-jay, red-breasted nuthatch, white-breasted nuthatch, and plain titmouse. Typical over-wintering birds are the common raven and mountain chickadee.

On a regional basis, the term pinyon-juniper woodland most adequately describes the overall habitat types of the Tract C-b study area. Just outside the study area boundary, above approximately 7600 feet, the zone of pinyon-juniper woodland gives way to the shrubland type.

3.3.4.10 Chained Pinyon-Juniper Rangeland

The chaining program of the BLM has created large blocks of open areas within the pinyon-juniper woodland. These areas are distinctive, consisting of fallen trees with shrubs and grasses characteristic of the understory of pinyon-juniper. Areas such as these are important to livestock and wintering deer, desert

cottontail, and least chipmunk. Small mammal populations have increased in the chained areas, thereby increasing the amount of prey for coyotes, raptors, and other predators of small mammals. The absence of overstory vegetation allows penetration of sunlight to the ground, stimulating the proliferation of a diverse and relatively dense ground cover. Several ridge tops were chained by the BLM throughout the basin. The Tract C-b study area has roughly 45 percent of its total area chained.

3.3.4.11 Burned Areas

"Burned areas" occur within the pinyon-juniper woodland at several locations. The clearings resulting from these old fires are usually characterized by widely-spaced dead trees and a ground cover of Indian ricegrass. These openings provide grazing area for cattle and deer and feeding areas for seed-eating birds.

3.3.4.12 Rimrock

Most of the sandstone cliffs and ledges occur in the major valley bottoms. The tops of the cliffs are often near pinyon-juniper woodlands and provide important denning and nesting areas for both birds and mammals. Red-tailed hawks are the most frequent raptor users of rimrock for nesting. Golden eagles are less abundant and nest only in the highest cliffs. Falcons require nesting cliffs that are steeper than those encountered throughout the basin. Bobcats and several small mammals, including the bushy-tailed woodrat and chipmunk, also make extensive use of rimrock habitat. Bushy-tailed woodrats build large communal nests in eroded sandstone pockets and rimrock areas.

3.3.4.13 Douglas-fir Forest

Douglas-fir forests are limited within the Piceance Basin, attaining greatest development at higher elevations, occurring only sporadically at lower elevations on cool north-facing slopes. The isolated stands that occur on Tract C-b are restricted to the steeper north-facing slopes and are represented in some cases by fewer than a dozen trees. The red squirrel or chickaree, a characteristic mammal of Douglas-fir forests, has been sighted on two occasions within the Tract C-b study area; it appears to be locally rare even among larger Douglas-fir stands in the area.

3.3.4.14 Aspen Woodlands

Aspen woodlands have a distribution pattern similar to the Douglas-fir forest. Both tend to occur as discrete plant communities at higher elevations. Aspen stands support porcupines, summering deer, long-tailed vole, and Gapper's red-backed vole. Aspen do not occur in the Tract C-b study area but do occur at the upper end of the C-b corridor (Figure 3-5) and at other north and northeast-facing high-elevation sites in the Basin. Typical bird species inhabiting aspen stands are the house wren, the yellow-rumped warbler, the western flycatcher, and the long-eared owl. In the fall and winter, gray-headed junco, mountain chickadee, and black-capped chickadee remain.

3.3.4.15 Summary

The major habitat types that occur on Tract C-b are found throughout much of the Piceance Basin. None are unusual in structure or species habitation. Habitat distribution has shifted to a more open habitat type consisting of grasses, shrubs, saplings, and slash due to BLM's chaining of the pinyon-juniper woodlands on approximately 45 percent of the Tract. This increase in the rangeland habitat has favored livestock, deer, and small mammals, while limiting available pinyon-juniper woodland habitat for the pinyon mouse, pinyon jay, and other animals dependent on this habitat. This habitat reduction results in reduced populations of animals dependent on the pinyon and juniper for food and shelter.

3.3.5 Predators

Large, predatory animals within the region do not demonstrate a distinctive association with a particular habitat type. Rather, they generally tend to range throughout most or all habitat types in search of suitable prey.

Coyotes, bobcats, weasels, and badgers probably range over the entire Tract C-b study area, where they feed primarily on birds, mice, rabbits, and ground squirrels. In terms of abundance, the coyote is probably the most important mammalian predator in the Piceance Basin and the study area.

Although dietary information for the coyote has not been gathered on Tract C-b, when rodents such as ground squirrels and chipmunks become abundant during the warm months, they are probably fed upon extensively by the coyotes. During the winter period these rodents are inactive, and coyotes probably resort to feeding heavily on carrion resulting from natural mortality of mule deer. Rasmussen (1941) examined coyote scat collected during mid-winter from a pinyon-juniper ecosystem in northern Arizona. He found the scat to consist

principally of deer hair and bones, some rabbit fur, and the remains of deer mice. He found both mule deer carrion that had been fed upon by coyotes and fresh mule deer that apparently had been killed and eaten by coyotes. Coyote scats collected during summer from the same area by Rasmussen (1941) consisted primarily of juniper berries, service berries, prickly pears, grass, and rodent remains.

Large avian predators such as hawks, owls, and eagles range throughout the Tract C-b study area where they prey on small mammals and birds and assist in controlling the populations of these animals. Ravens are generally considered scavengers, but have been known to take live prey, particularly small mammals and birds.

Golden eagles, great horned owls, kestrels, and ravens are the most important year-round avian predators in the Piceance basin. Red-tailed hawks are common during the warm months in the study area, but their numbers dwindle with the onset of winter. Rough-legged hawks are common in the study area only during winter.

Golden eagles range throughout the entire study area during all seasons. They are opportunistic in their feeding habits and their diet in the region of the Piceance basin ranges from mule deer carrion in the winter, to rodents such as ground squirrels during summer. In other areas, golden eagles have been known to feed heavily on rabbits when this group is abundant.

Great horned owls are found within the Tract C-b study area during all seasons. Owl pellet studies conducted in the study area revealed that in this area of the Piceance Basin great horned owls feed almost exclusively on microtine rodents (voles) throughout the year.

Ravens are common scavengers found throughout the study area all year. They probably feed heavily on both dead cattle and mule deer during winter. Pellet studies indicated that ravens in this region of the Piceance basin also feed on small mammals and birds. Both red-tailed and rough-legged hawks range throughout the region where they feed upon a wide variety of rodents including deer mice, voles, ground squirrels, and chipmunks.

3.4 Aquatic Biota

3.4.1 Introduction

Northwestern Colorado is well known for its fisheries resources and for the variety of its streams. The two largest streams in the oil shale region are the Colorado River to the south and the White River to the north of the Piceance Basin. The major drainages of the basin are Piceance Creek and Yellow Creek.

Piceance Creek originates at the eastern edge of the Piceance Basin and flows 80 km to its confluence with the White River to the northwest. It arises from springs throughout the basin which originate from ground water discharge of the Green River Formation. The Evacuation Creek Member of the Formation contributes ions, predominantly calcium, magnesium, and bicarbonate in the upper portion of Piceance Creek. Water contributed by the Uinta Formation aquifer and the Parachute Creek Member aquifer shows a gradual increase in sodium (from nahcolite) in the lower portion until it becomes the dominant cation (Coffin et al. 1971). Flow on Piceance Creek ranges from 0.014 to 2.8 m^3/sec (Everhart and May 1973).

The upper portions of Piceance Creek are usually dry in summer and fall months. Runoff from spring snowmelt in April and subsequent rainfall can cause extremes in width, depth, and flow. The exposed sandstone bedrock and sparse vegetation of the upper draws do little to contain rapid runoff during thunderstorms, thereby allowing formation of steep canyons and gulches.

Aquatic communities vary seasonally, with fluctuations in food abundance, water temperature, and flow. Flow is an important factor determining the type of substrate. Unstable, fine gravel substrates are a constraint to aquatic invertebrates in lower Piceance Creek (Everhart and May 1973). Riparian plant communities along permanent water consist mainly of sedges, rushes, horsetails, a few grasses, marsh elder, mallow, nettle, sunflower, and goldenrod. Willows are restricted to small, isolated areas (Annual Summary and Trends Report 1975).

Lower Piceance Creek sites have the harshest physical and chemical environments. These sites are characterized by high dissolved solids concentrations, high turbidities, a wide temperature range, anchor ice during the winter, and an unstable, gravel substratum. The high concentrations of dissolved solids are partially the result of irrigation activities; however, they are primarily due to inflows

of highly saline ground water from the lower Parachute Creek Member aquifer, both from small surface springs and interconnections with the alluvial aquifer (Weeks and Welder 1974, Weeks, et al. 1974). The high turbidities are caused by increased flows combined with smaller sediment particles and, to a lesser extent, by agricultural return flows. Since the lower sites are some distance from either large springs or tributaries, the range of temperatures is greater, thus causing high temperatures in the summer and anchor ice in the winter.

Except for Piceance Creek and its few tributaries, little free water exists in the Piceance Basin near the Tract. Stewart and Willow Creeks border the study area of Tract C-b on the east and west and are the only nearby perennial streams. Generally, the basin is dry and permanent flowing or standing water is limited to the major drainages, such as Piceance, Black Sulfur, Stewart, and Willow Creeks, and Ryan Gulch. A few man-constructed reservoirs are present within meadows along Piceance Creek and its major tributaries. Other gulches support only intermittent flow.

No dams exist on Piceance Creek comparable with the large dams on some other local drainages (e.g., Lake Avery, tributary to the White River). Small earthen dams in dry gulches have been constructed by ranchers and land managers to provide watering sites for livestock and wildlife.

The Federal Oil Shale Leasing program has prompted a variety of studies of aquatic systems in the Piceance Basin. The C-b Shale Oil Project and Rio Blanco Oil Shale Project have compiled detailed reports on aquatic ecosystems on these leased areas. Everhart and May (1973) did extensive fish sampling in lower Piceance Creek, reporting ten species of fish. C-b studies report seven of those species and one additional species (Annual Summary and Trends Report 1976). Studies sponsored by Government agencies, primarily EPA research grants to universities, have been aimed at larger study areas and will provide information which will permit placing the aquatic systems of energy impacted areas into a regional perspective (Goettl and Edde 1975).

Aquatic macroinvertebrates were investigated by Pennak (1974) and Ward (1975). Biomass values reflected seasonal changes and no clear-cut temporal or spatial pattern. Species diversity is higher at upstream sites than at downstream sites, and tributaries (except for Black Sulfur Creek) show low diversity.

Regionally, the same large groups of aquatic macroinvertebrates found in Piceance Creek and its tributaries are present in cold water streams of higher elevations and in warm water and the larger streams and rivers at lower elevations. These groups include the Annelida (leeches and aquatic earthworms), the Arthropoda (Mayflies, damselflies, dragonflies, stoneflies, and aquatic beetles), and the Mollusca

(snails and clams). Species in these major groups vary throughout the region depending on water temperatures, flow rates, and pollution sources. Generally, the colder streams have the greater species diversity, especially species of Arthropods, excepting stoneflies. These streams have better water quality than the warmer, slower moving streams, including higher dissolved oxygen content, lower suspended solids, and lower salinity. Warmer streams are characterized by a greater predominance of leeches and aquatic worms and other species characteristic of higher organic concentrations, such as true-flies and snails.

The following treatment on aquatic ecology of the oil shale region is a very generalized overview of the physical environment in relation to the organisms of principal human interest, the fishes.

3.4.2 Physical Environments of Streams

Elevation is one important factor in determining the type of environment which exists in a stream. In general, high altitude streams (above 5000 feet) are characterized by low water temperatures, swift flow, low salinity, high dissolved oxygen, and high quality fish habitat. Cold-water fish, such as trout, can thrive under conditions where the dissolved oxygen is greater than 7 ppm and where there are abundant supplies of benthic macroinvertebrates for food and streamside vegetation for cover (Colorado Division of Wildlife 1976). The North and South Forks of the White River, east of Meeker are prime examples of this type of excellent fish habitat.

The transitional zone between high-elevation, cold mountain streams, and the lower-elevation main streams supports a mixed population of fish which reflects an overlap of the more tolerant cold water and the warm water species. Water quality is usually intermediate between that exhibited by the clean mountain streams and the low elevation main streams. Nutrients, suspended solids, temperature, and salinity are generally higher while dissolved oxygen is usually lower in this transitional zone (Colorado Division of Wildlife 1976). The segment of the White River bordering the north edge of the basin offers a good example of such a habitat. Its maximum temperature is about 24°C (75°F), nutrient levels are elevated by runoff and organic enrichment by man, and silt loads are increased compared to the upstream situation.

The lower elevation streams of the area are characterized by high sediment loads, high salinity, low dissolved oxygen, and higher temperatures. These are considered warm water fish habitats with forage fish predominating. The Colorado River south of the basin is an example of a warm stream, which supports abundant catfish, carp, and sucker populations (Colorado Division of Wildlife 1977).

Piceance Creek can be characterized as a cold water stream. The maximum water temperature recorded during the past two years was 18°C (65°F). With respect to overall water quality, Piceance Creek most closely resembles the transitional zone previously discussed.

High dissolved and suspended solids, high specific conductance, elevated nutrient levels, and high sulfate levels indicate that Piceance Creek is not a high quality fish habitat; the low temperature and fairly high dissolved oxygen levels in the stream allow some cold water fish species to inhabit Piceance Creek.

3.4.3 Fish Distribution

The fish populations of the western slope of Colorado differ from those of the eastern slope. The eastern slope rivers generally contain fish species characteristic of the Great Plains (i.e., Nebraska and Kansas), while the western slope rivers have a different species composition. The Continental Divide acts as a geographic barrier to fish migration. The distribution of suckers illustrates this difference; the western white sucker is found only on the east side of the Divide, while flannelmouth suckers and blue-head suckers are found in the west (Cockerell 1927).

A species that inhabits streams only in the northwest sector of Colorado is the mountain whitefish. Whitefish have not been collected in Piceance Creek or near Tract C-b, but they have been collected from the White River west of Meeker above and below its confluence with Piceance Creek. Its typical distribution is further to the north, from Wyoming to northern British Columbia. Spawning occurs in late fall or early winter over gravel or rubble. Whitefish prefer large, cold streams, but they may have the ability to adapt to changing conditions of development (Scott and Crossman 1973).

The blue-head sucker has been collected from the White River and Parachute Creek (Colony EIS). In Colorado, the mountain sucker has been recorded only in the Piceance Creek drainage in the Tract C-b region and in Trout Creek, about 100 miles to the northeast (Goettl and Edde 1975). On Tract C-b this species was collected from Willow and Stewart Creeks, and from the Redd Cow Camp reservoir in Stewart Gulch.

Suckers are termed "forage" species because they provide food for game fish such as trout. Rough and forage fish are typical of the fish community of the White River. Rough and forage fish inhabiting the Piceance Creek drainage include the mountain sucker, speckled dace, and mottled sculpin.

In addition to these species, Parachute Creek, draining the southeast portion of the Roan Plateau, supports rainbow trout and cutthroat trout at its upper end. Brook trout, introduced from the

eastern U.S., are well established in Colorado and are the predominant trout in Piceance Creek and its tributaries. Brown trout and rainbow trout are other introduced species that have thrived. Of all trout caught in the Colorado River drainage by fishermen, 26 percent have been brook trout (Colorado Division of Wildlife 1976).

Brown trout were imported from Europe in 1883. They have done well in the sediment laden streams of western Colorado. About 13 percent of the Colorado trout catch is brown trout. These introduced species have hybridized with or supplanted the native cutthroat trout (Colorado Division of Wildlife 1976).

Only a limited number of brown and rainbow trout were captured near Tract C-b. Mountain suckers, brook trout, and speckled dace were the most abundant fish species occurring in Piceance Creek during the period of baseline investigations.

3.4.4 Local Influences on Aquatic Systems

The more important factors affecting the aquatic ecosystems of the region are related to various types of land use activities and the introduction of exotic fish species. The primary land use changes which are tending to degrade the quality of the existing aquatic ecosystems in the oil shale region of northwestern Colorado include: a) irrigation and return flows which deplete stream flow and increase salinity, b) dams which eliminate spawning and feeding habitat of riverine fish and disrupt migratory pathways, c) toxic agricultural chemicals, d) trampling and destruction of streamside vegetation by livestock, and e) agricultural runoff which increases biochemical oxygen demand (BOD) and decreases dissolved oxygen levels and increases salinity (Ellis 1914). The introduction of exotic fish species, e.g., rainbow trout and brown trout, whether deliberate or accidental, causes competition between the exotic species and the native inhabitants for similar niches. This causes a shift in ecosystem functioning, and usually results in a decreased diversity of species since a successful exotic often demonstrates a competitive advantage for food and habitat over the native species.

3.4.5 Summary

There are no perennial flowing or standing waters within the Tract C-b lease boundaries. However, Piceance and Willow Creeks and ponds formed from their tributaries are within the study area. The largest of these, Piceance Creek, can be characterized as a cold water stream, spring and ground water fed, high in dissolved solids and specific conductance with elevated nutrient and sulfate levels, that become more concentrated towards its confluence with the White River. Low temperature and fairly high dissolved oxygen levels fur-

nish a wider diversity of aquatic fauna than one might expect. Eight species of fish have been reported from Piceance Creek near the Tract, including three species of trout. The most common fish observed are mountain suckers, speckled dace, and brook trout. Piceance Creek is one of only two known locations for the mountain sucker in Colorado.

3.5 Threatened and Endangered Species

3.5.1 Introduction

During two years of intensive baseline investigations of the terrestrial and aquatic biota of the Tract C-b region, no evidences of species designated as threatened or endangered by the federal government have been observed; only one species, officially designated as endangered by the State of Colorado, the greater sandhill crane, has been noted in the Tract vicinity. Some localities in the Piceance basin do support such classified species, and certain threatened or endangered species undoubtedly will briefly appear on or over the Tract on an occasional basis, generally during migration. The following summary provides an overview of potential occurrence in the Tract region of plants and animals given threatened or endangered status.

3.5.2 Vascular Plants

A growing concern relative to the fate of rare plant species has resulted in the recent preparation of lists of endangered species in accordance with requirements of the 1973 Endangered Species Act. The first attempt to prepare a list of nationally endangered plants was undertaken by the Smithsonian Institution (1975), and classifications were made in the Federal Register (June 16, 1976).

Two recent publications by Weber (1976) and Weber and Johnston (1976) present a more liberal interpretation of what constitutes endangered species, and also provide an unofficial list which includes the local status of plants within Colorado. Weber and Johnston (1976) include approximately 150 species which they consider to be endangered, and over 400 others which they list as rare. As defined by the Smithsonian Institution (1975), "A rare species of plant is one that has a small population within its range."

Compilation of a meaningful list of endangered species for any area within Colorado is possible by combining entries from these national and unofficial state lists. A list of endangered species for the Piceance Basin was developed by referring to all of the above reports and then isolating those species which occur within the Piceance Basin. Identifications of those species which occur in the Piceance Basin were made on the basis of personal observations of scientists working in the Basin, from species lists included in

consulting reports (Colony Development Operation 1974, Thorne Ecological Institute 1974), and from the Manual of Colorado Plants (Harrington 1954). The list on Table 3-3 is most reliable for the central and higher portions of the Piceance Basin. South of the Tract, in the Parachute Creek and Roan Creek drainage systems, numerous species which are more characteristic of the Great Basin-Intermountain West region farther to the west are found. The unique environmental characteristics of the Wasatch shales and Mancos shales (e.g., high selenium content, Weber pers. comm. 1973) has produced a group of species which are restricted to these areas, and as such constitute a group of local endemics. These species are included in Table 3-3 even though their known distribution does not include the Piceance Creek watershed.

During the two-year baseline period none of the species listed in the table were observed on Tract C-b or within the 1-mile study zone surrounding the Tract. Infrared photography of the area was studied to identify mesic sites or box canyons that might provide the necessary habitat for certain of the endangered species (e.g., Rhamnus smithii, Sullivantia purpusii, or Aquilegia barnebyi). These sites were then examined in the field to determine if any of these species occurred. Dry, exposed sites were searched carefully for species such as Astragalus lutosus and Festuca dasyclada. To date, no plant species considered to be endangered, either at a national or local level, has been observed on or close to Tract C-b.

3.5.3 Mammals

Table 3-4 lists species of mammals designated as threatened or endangered in the Federal Register or by the State of Colorado Division of Wildlife. None of these species were observed in the study region, nor is it likely that any will occur in the immediate vicinity of Tract C-b. The reasons for this conclusion are briefly stated below:

Brown bear (Grizzly bear) (Urus arctos): although the grizzly bear is officially listed as "Endangered" in Colorado, it may no longer exist in the state. No recent sightings have been reported from the state, and grizzly bears have not inhabited northwestern Colorado for many years.

Black-footed ferret (Mustela nigripes): the black-footed ferret is listed as endangered both nationally and in Colorado. Its former distribution was believed to extend from the short-grass prairie of the Great Plains to eastern Arizona, Utah, Wyoming, and Montana (Hall and Kelson 1959). The geographic distribution closely corresponds to the former distribution of prairie dogs, which are believed to have been the black-footed ferret's principal prey. According to Finley (1976), the only definite record of the black-

Table 3-3 LIST OF ENDANGERED OR THREATENED PLANT SPECIES OF THE PICEANCE BASIN REGION

Species	Reference		
	Weber and Johnston (1976)	Federal Register (June 16, 1976)	Smithsonian Report 94-A (Federal Register-July 1, 1975)
Aquilegia barnebyi	Endangered	Not Listed	Not Listed
Astragalus detritalis	Rare	Endangered	Endangered
Astragalus lutosus	Endangered	Not Listed	Endangered
Caulanthus crassicaulis	Endangered	Not Listed	Not Listed
Coryphantha vivipara	Endangered	Not Listed	Not listed
Cryptantha stricta	Rare	Not Listed	Threatened
Echinocereous triglochidiatus (all varieties)	Endangered		
var. inerme		Endangered	Not Listed
Festuca dasyclada	Endangered*	Endangered	Not Listed
Parthenium ligulatum	Rare	Endangered	Not Listed
Pediocactus simpsonii	Endangered	Not Listed	Not Listed
Phacelia submutica	Endangered	Endangered	Not Listed
Rhamnus smithii	Endangered	Not Listed	Not Listed
Sullivantia purpusii	Endangered	Not Listed	Threatened

*not listed but considered by Weber to be endangered (personal communication).

Table 3-4 ENDANGERED AND THREATENED MAMMALS OF THE INTERMOUNTAIN WEST

NATIONALLY ENDANGERED OR THREATENED*

Common name Scientific name	Official Status	Identified or expected on Tract C-b study area
Brown bear ("Grizzly Bear") *Ursus arctos*	Threatened	No
Black-footed ferret *Mustela nigripes*	Endangered	No
Northern rocky mountain wolf *Canis lupus irremotus*	Endangered	No

STATE ENDANGERED OR THREATENED**

Common name Scientific name	Official Status	Identified or expected on Tract C-b study area
Black-footed ferret *Mustela nigripes*	Endangered	No
Gray wolf *Canis lupus*	Endangered	No
Grizzly bear *Ursus arctos*	Endangered	No
Lynx *Lynx canadensis*	Endangered	No
River otter *Lutra canadensis*	Endangered	No
Wolverine *Gulo gulo*	Endangered	No

* Federal Register, Vol 41, No. 208, October 27, 1976

** Colorado Division of Wildlife, March 27, 1975

footed ferret in the oil shale region of Colorado was reported near Meeker by Felger (1910). Since there have been no recent reports of the black-footed ferret in northwestern Colorado, and because no prairie dogs occur in the vicinity of Tract C-b, the possibility of its occurrence is highly unlikely.

Northern rocky mountain wolf (Canis lupus irremotus): this subspecies of wolf is considered by the U.S. Department of the Interior to have a present-day distribution in Wyoming and Montana. Wolves were common in the Piceance Basin in the early 1900's, but they were exterminated because of livestock interests. No sightings have been reported in northwestern Colorado in recent years.

Lynx, (Lynx canadensis): The lynx is a state endangered species. Its former distribution included the boreal forests of Colorado (Armstrong 1972), but it was probably never abundant (Lechleitner 1969). Much uncertainty exists among the early accounts of the Lynx in Colorado since this species was often confused with the bobcat. No sightings have been reported from northwestern Colorado in recent years.

River otter (Lutra canadensis): the river otter is classified as an endangered species in Colorado. Little information is available on its original distribution within the state, and only a few specimens exist from early collections. Most accounts by the early naturalists suggest that the river otter was never abundant in Colorado, although it apparently was widespread (Armstrong 1972). It originally occurred in the White River, but whether it occurred in Piceance Creek is unknown. No recent sightings have been reported in this area.

Wolverine (Gulo gulo): the wolverine is classified as an endangered species in Colorado. According to the Colorado Division of Wildlife, it may no longer exist in the state. Originally, it occurred in mountainous regions of the state. Several old records suggest it once occurred in Rio Blanco County (Armstrong 1972), but no recent sightings have been reported.

3.5.4 Birds

Birds are highly mobile; thus, it is probable that from time to time species designated as threatened or endangered will appear on or very close to Tract C-b. Three species in particular are likely candidates for occasional appearances in the Tract vicinity: American peregrine falcon (Falco peregrinus anatum), greater sandhill crane (Grus canadensis tabida), and whooping crane (Grus americana). Probabilities of occurrence in the area for these species are briefly discussed here.

Three subspecies of the peregrine falcon occur in North America: Falco peregrinus anatum, F. tundrius, and F. pealei. Both anatum and tundrius subspecies are listed as endangered in the Federal Register. Breeding populations of the endangered F. anatum have declined in the Rocky Mountain region of their range during the last 20 years. During 1974, only five Colorado pairs successfully produced fledglings, and only three nesting pairs were successful in 1975 (G. Craig, Colorado Division of Wildlife, personal communication 1975). Peregrines are known to be very restrictive in their selection of eyrie sites (Snow 1972). Preferred cliffs are usually in close proximity to water and are usually high. Fifteen known Colorado nests are all on cliffs higher than 70 meters. No nests have been located in the Piceance Creek basin, and because there are no cliffs in the basin offering the height or vantage normally preferred by peregrines, it is unlikely that prime nesting sites are present. While peregrines have not been observed on or near the Tract, a number of sightings have been made 10-15 miles northwest of the Tract; peregrines have also been seen in the Parachute Creek area south of the Tract. It is likely that this falcon will traverse the Tract area from time-to-time, but it is clear that suitable nesting habitat is not available in the immediate Tract vicinity.

The greater sandhill crane nests in northwestern Colorado at various points along the Yampa River, in California Park, and in the Steamboat Lake area. It is not listed in the Federal Register Endangered Species List (1976); however, the Colorado Wildlife Commission considers greater sandhill cranes that nest within Colorado to be endangered. This designation does not apply to cranes that temporarily stop within Colorado during migration between wintering areas in New Mexico and breeding locations in Wyoming, Utah, and Idaho. Greater sandhill cranes have been sighted along Piceance Creek on several occasions during migratory periods, and some were observed during October 1975 near Tract C-b.

During 1975 and 1976, intensive surveys were made in various parts of the basin by a number of groups to determene whether these birds were nesting in the Piceance Creek basin. No evidence of crane nesting was found during these surveys, and it appears that these cranes utilize portions of the basin as resting and feeding areas during migration.

During 1975, whooping crane eggs were taken from whooper nests in Canada and placed beneath greater sandhill cranes incubating eggs on Grays Lake National Wildlife Refuge in Idaho. A number of young were raised by foster parents, migrated with their parents to sandhill crane wintering grounds in southern New Mexico, and returned during spring 1976 to Idaho. During early May 1976, a single juvenile whooping crane was observed foraging with four

juvenile greater sandhill cranes in a meadow about 10 miles northwest of Tract C-b. This bird was in all probability a foster bird raised by greater sandhill cranes in Idaho. It is likely that individuals of this experimental whooping crane flock will fly over the Piceance Basin from time to time during future migration periods. The Basin provides no suitable nesting habitat for this endangered species.

3.5.5 Fish

Table 3-5 identifies fish species occurring in Colorado that are designated as threatened or endangered by the Colorado Wildlife Commission or in the Federal Register. Some of these species, such as the Arkansas darter and the Arkansas River speckled chub, are not distributed in northwestern Colorado.

None of the species listed in Table 3-5 has been noted during studies in Piceance, Willow, and Stewart Creeks. In Colorado, the mountain sucker (Catostomus platyrhynchus) is considered unique to the Piceance Creek basin (Letter from Dr. R. Behnke, Department of Fishery and Wildlife Biology, Colorado State University). Although it is not recognized by the State of Colorado as threatened or endangered, it may be considered of special interest because of its restricted distribution within Colorado. In addition to its occurence in the Piceance Creek basin, the mountain sucker also occurs in Utah (Sigler and Miller 1963), Montana, Wyoming, and some other western states and parts of Canada (Scott and Crossman 1973, Hauser 1969, Smith 1966).

3.5.6 Reptiles and Amphibians

Of the five species of reptiles (consisting of four lizards and one snake) and two species of amphibians that have been observed on Tract C-b, none are considered endangered or threatened.

3.5.7 Summary

No threatened or endangered flora or fauna have been observed as residents on Tract C-b or the surrounding one mile study area. Migrating birds designated as threatened or endangered (whooping cranes, greater sandhill cranes, and American peregrine falcons may be periodically sighted in or around Tract C-b, but none are considered residents or have been observed nesting on the Tract or study area. The mountain sucker found in Piceance Creek is considered unique to Colorado because of its disjunct distribution, but is not considered nationally threatened or endangered since it is common further north and west.

Table 3-5 FISH SPECIES DESIGNATED AS THREATENED OR ENDANGERED IN COLORADO

Common Name	Scientific Name	Wildlife Commission State of Colorado	Federal Register (October 1976)
Bonytail chub	Gila elegans	Endangered	Not listed
Humpback chub	Gila cypha	Endangered	Endangered
Arkansas River speckled chub	Hybopsis aestivalis tetranemus	Threatened	Not listed
Colorado River squawfish	Ptychocheilus lucius	Endangered	Endangered
Humpback sucker	Xyrauchen tenanus	Endangered	Not listed
Greenback cutthroat	Salmo clarki stomias	Threatened	Endangered
Colorado River cut-throat	Salmo clarki pleuriticus	Threatened	Not listed
Rio Grande cutthroat	Salmo clarki virginalis	Threatened	Not listed
Central Johnny darter	Etheostoma nigium	Threatened	Not listed
Plains orange throat darter	Etheostoma spectabile pulchellum	Threatened	Not listed
Arkansas darter	Eheostoma cragini	Threatened	Not listed

4.1 Introduction

In addition to generating data on the physical and biological environment the two years of baseline investigation were also concerned with the cultural setting of the C-b Oil Shale Tract. The history of the area, the possibility of finding relics of that history, the use to which the pioneers put the area, the susceptibility of the area to outside forces, and how the physical and biological attributes of the area are viewed by the local residents and visitors all became important to the project.

Archaeology and socio-economic studies provide most of these data. The determination of how man viewed the area and his perception of the aesthetic value was provided by a study of the scenic values as outlined by the U.S. Forest Service's Visual Management System. In preparing the sequence of subjects for presentation it seems natural for the discussion of scenic values to precede others in the cultural setting, since appreciation of the aesthetics of an area links the physical-biological attributes with man. Certainly without man's perception of his environment there would be no scenic value.

An area may be a focal point for several reasons. It may be of geologic interest or cultural significance to man and at the same time be an important wildlife habitat. For example, Scandard Gulch is noted in three different instances: the Scandard Gulch sandstone cliffs are important geologically and visually, and the interspersed lateral draws are important as critical deer winter range. Understanding the distinctions between disciplines allows us to identify the overlapping interests in describing environments. Visual qualities are one of many approaches to describing an area.

4.2 Scenic Values

4.2.1 Introduction

A study was undertaken to determine the type and quality of the scenic resources existing in the Tract area. The scenic elements of the Piceance Creek basin were related specifically to the Tract and generally to the scenic resources of surrounding areas. This information was then used to define and evaluate areas of Visual Sensitivity on the Tract.

4.2.2 Methodology

The methodology and guidelines used in this study were taken from the U. S. Forest Service's Visual Management System (USDA Handbook No. 462). (The Bureau of Land Management developed their own system subsequent to the Forest Service publication of Handbook 462). The study area covered the Tract and a zone within four miles of the Tract boundary.

The fourth Quarterly Data Report (1975) for Tract C-b contains a discussion of landscape and human factors of the Piceance Creek basin. In this study scenic values are evaluated according to Sensitivity Classes derived from the interrelationship of these aspects.

Landscapes are described in terms of form, line, color, and texture and have been classified as distinctive, common, or minimal. The latter classifications are referred to as Variety Classes and are used to distinguish landscapes, i.e., landforms, rockforms, vegetation, and waterforms (Table 4-1). Within the Piceance Basin, there are considerable variations in these landscapes.

To account for the human aspects of the visual experience in this scenic quality analysis the methodology includes a measurement of the relative importance of user areas, water bodies, and travel routes, viewers' concern for scenic values, and the distance from which the landscape is viewed. User areas are rated as being of primary or secondary importance based on size, volume of use, duration of use, recreational use, and local importance (Table 4-2). To account for the concern for scenic values which the users of the Piceance Basin have, a matrix was developed incorporating the importance of User Areas and the percentage of users having some concern for scenic values (Table 4-3). Using Distance Zones as defined in Table 4-4 along with Sensitivity Levels and Variety Classes the final depiction of Sensitivity Classes is accomplished (Tables 4-5 and 4-6).

Table 4-1

VARIETY CLASSES DETERMINATION*

	DISTINCTIVE	COMMON	MINIMAL
LANDFORM	Cliffs on valley sides Highly eroded slopes	Moderately steep valley sides, flat ridge tops, and flat valley bottoms	Extensive flat ridge tops or valley floors
ROCKFORM	Rock features which stand out on landform Unusual rock strata exposures	Rock features obvious but do not stand out	Rock features small to non-existent
VEGETATION	High degree of patterns in vegetation High diversity in plant forms Relatively large stands of trees	Continuous vegetative cover with some degree of pattern Low diversity in plant forms Irrigated meadows	Continuous vegetative cover with little or no pattern Chained or sprayed areas Non-irrigated valley bottoms
LAKES, PONDS	Irregular shorelines Greater than one acre in size	Regular shorelines Less than one acre in size	No lakes or ponds
STREAMS, SPRINGS, AND SEEPS	Springs and seeps which form ponds Perennial streams Large volume	Springs and seeps which do not form ponds Ephemeral streams Low volume	No streams, springs, or seeps

*Only one of the criteria had to be met for an area to be classed as Distinctive, whereas two or three criteria had to be met for an area to be classed as Minimal. This allowed Distinctive areas to be readily identified while Minimal areas needed considerably more factors for them to be classified.

Table 4-2

USER AREA CRITERIA

	PRIMARY IMPORTANCE	SECONDARY IMPORTANCE
TRAVEL ROUTES Roads Trails	High use volume Major access road Long use duration	Low use volume Project road Short use duration
USE AREAS Overlooks Camp areas Ranch headquarters Cow camps	Large size Long use duration High use volume	Small size Short use duration Low use volume
WATER BODIES Ponds Streams	High recreation use	Low recreation use

Table 4-3

VIEWER SENSITIVITY LEVELS

User Area	Viewer Sensitivity Levels 1	2	3
Primary	At least 1/4 of users have SOME concern for scenic values (PICEANCE CREEK ROAD AND RANCH HEADQUARTERS).	Less than 1/4 of users have SOME concern for scenic values (COLLINS GULCH ROAD).	
Secondary	More than 3/4 of users have SOME concern for scenic values.	Between 3/4 and 1/4 of users have SOME concern for scenic values (ALL OTHER INTENSIVE STUDY AREA ROADS).	Less than 1/4 of users have SOME concern for scenic values (AREAS NOT SEEN FROM ANY USER AREA).

Table 4-4

DISTANCE-ZONE CRITERIA

	Foreground	Midground	Background
Distance (miles)	0 to 1/4-1/2	1/4-1/2 to 3-5	3-5 miles to infinity
Sight capacity	Detail	⟵――――⟶	No detail
Object viewed (example)	Rock point	Entire ridge	System of ridges
Visual characteristics	Individual plants & species	Texture and Form (conifers/ hardwoods)	Patterns (light and dark)

Table 4-5

SENSITIVE AREAS - QUALITY OBJECTIVES COMPARISON

Sensitivity Class	USFS Visual Quality Objective	Degree of Acceptable Change
A	Retention	Should not be evident
B	Partial Retention	Should be visually subordinate
C	Modification	May be visually dominant but must possess visual characteristics of natural landscape.
D	Maximum Modification	May be visually dominant but must possess visual characteristics of natural landscape when viewed as background.

Table 4-6

SENSITIVITY CLASS MATRIX *

Variety Class	Distance-Zone/Viewer-Sensitivity Level						
	Foreground, level 1	Midground, level 1	Background, level 1	Foreground, level 2	Midground, level 2	Background, level 2	Not Seen level 3
Distinctive	A	A	A	B	B	B	B
Common	A	B	B	B	C	C	D
Minimal	B	B	C	C	C	D	D

*Sensitivity Classes

A
B
C
D

Decreasing Sensitivity

Sensitivity Class A distinguishes those areas which have the most important structural features within view of a traveler or inhabitant. In decreasing order of importance are classes B, C, and D, rated by their lack of relief or distinctive features and their invisibility to the viewer.

To aid in retaining the scenic quality of lands described according to this classification system, the C-b Shale Oil Project will use the management guidelines, or visual quality objectives, developed by the U.S. Forest Service (Table 4-5). Since Class A is most sensitive, guidelines indicate these areas should have no evident change in form, line, color, and texture of the landscape. Class B areas will tolerate subtle changes in those qualities of the landscape, and C and D may have development activities which would dominate the landscape. The time for achievement of such visual qualities is shortest for Class A (immediately) and longest in Class D areas (five years). A more complete explanation of these guidelines as well as the other phases of the Sensitivity Class methodology are found in Oil Shale Tract C-b Quarterly Data Report No.4 (1975).

4.2.3 Scenic Description

The Piceance Basin is classified by Fenneman (1931) as a subtype of the Uinta Basin section, the Visual Character Type of the area. On the north, this section is bordered by the Uinta Mountains and on the south is composed of the Book Cliffs escarpment. The subtypes bordering the Piceance Basin are: Cathedral Bluffs and Douglas Creek to the west; Roan Cliffs to the south; the Grand Hogback to the east; and Colorow Mountains on the north.

The Piceance Creek basin was found to have low scenic value when compared to the other landscape types of the region. It contains marginal strength of form and line when compared to such character subtypes as the Book Cliffs, Roan Cliffs, Grand Mesa, and the Flattops, all of which have high relief, strong form, and great visibility with regard to color and texture. On a regional basis the Piceance Basin has an extremely low visual character because of the relatively low use, lack of long vistas, and rather undistinctive landscape.

The scenic values of the Piceance Creek basin were evaluated solely within the context of the basin itself. Within the Piceance Creek basin proper, the only Class A area near Tract C-b is the Piceance Creek road corridor. The Tract is located in an area determined to be of Sensitivity Classes B and C. The Sensitivity Class B areas include the principal drainage cutting through the Tract. The Class C areas comprise the chained regions, which cover approximately 45 percent of the Tract. The bottom of the on-Tract portion of Sorghum Gulch was rated as Class D since it is not visible from any user area (Table 4-5).

The assumptions made in this study were designed to maximize the scenic values which exist in the Piceance Creek basin; these values are marginal when compared to those existing in contiguous areas of western Colorado. The Sensitivity Class map (Figure 4-1) is a liberal interpretation of the Piceance Creek basin's scenic values, since most users' cone-of-vision does not expose them to many of the side gulches which contain the basin's distinctive landscapes. This was most evident to the field investigators who had considerable familiarity with the area but still found access to much of it solely as a result of completing this study.

It should be emphasized that this methodology accounts for scenic qualities seen by the majority of basin users. It does not account for small isolated areas that an individual hiker or hunter might encounter when traveling off established routes. Such areas are subject to individual preferences that no methodology designed to study regional scenic values can accomodate.

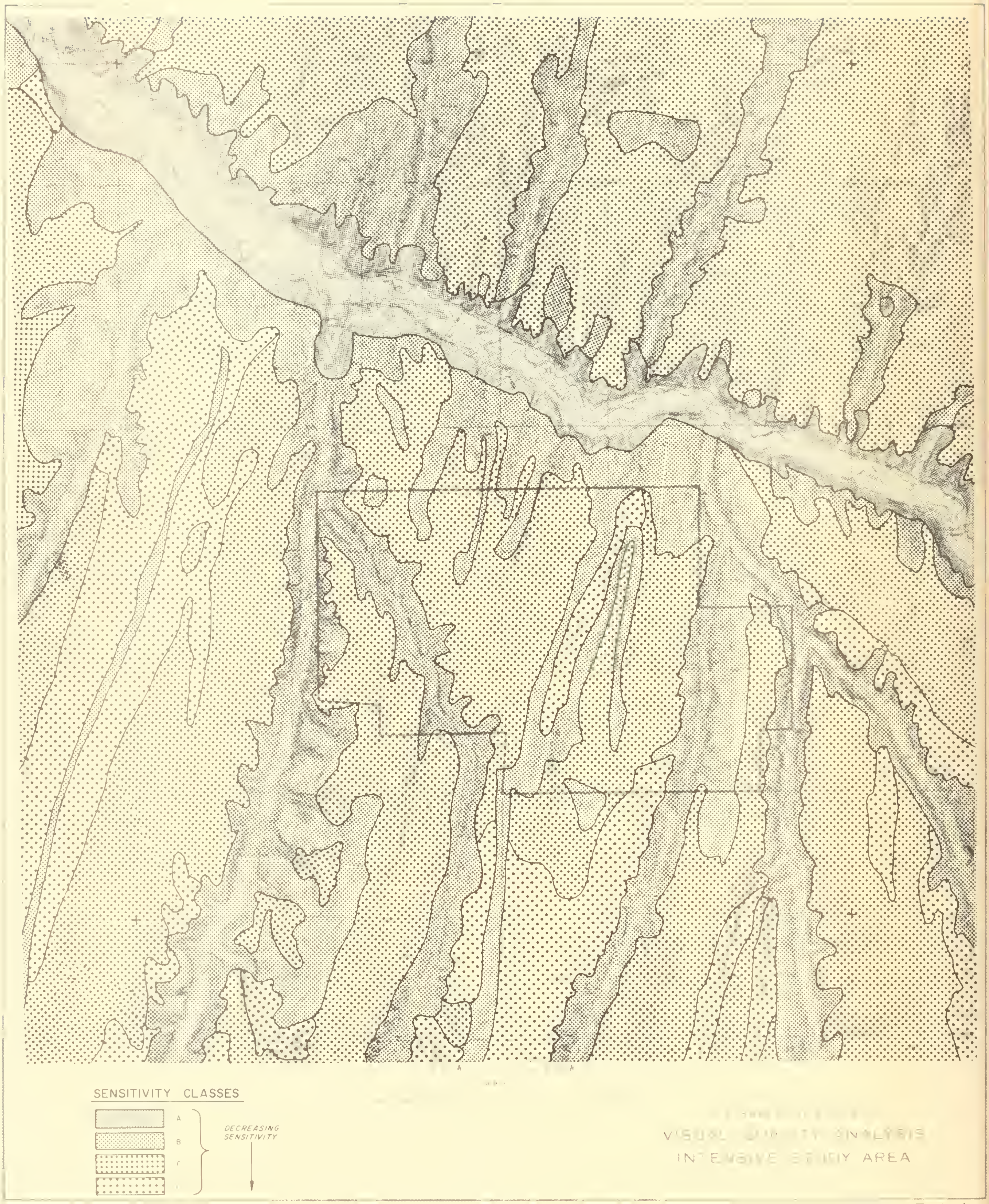

SENSITIVITY CLASSES
A
B
DECREASING SENSITIVITY
VISUAL QUALITY ANALYSIS
INTENSIVE STUDY AREA

FIGURE 4-1

4.3 Cultural and Paleontological Resources

4.3.1 Introduction

As a part of the environmental studies made in preparation for the development of Federal Oil Shale Lease Tract C-b, a program of archaeological reconnaissance was undertaken in August 1974 to fulfill the Lease Environmental Stipulations set forth by the Bureau of Land Management (USDI 1973).

> Sec. 6. Historic and Scientific Values. (A) Cultural Investigations. The Lessee shall, prior to construction or mining, conduct a thorough and professional investigation of any portion of the Leased Lands to be used, including, but not limited to, those to be used for mining, processing, or disposal operations or roads, for objects of historic or scientific interest, including, but not limited to, Indian ruins, pictographs and other archaeological remains. The Lessee shall report the results of these investigations to the Mining Supervisor before commencing construction and mining operations.
>
> (B) Objects of Historic or Scientific Interest. The Lessee shall not in any activities under this lease appropriate, remove, injure, deface, or alter any object of antiquity, or of historic, prehistoric, or scientific interest, including, but not limited to, Indian ruins, pictographs, and other archaeological remains. Where a question exists as to whether or not an object is of historic, prehistoric, or scientific interest or is an object of antiquity, the Lessee shall report to the Mining Supervisor for a final determination of which he shall inform the Lessee without unnecessary delay.

This project supplemented a less intensive reconnaissance of the Tract carried out in 1973 when one prehistoric site and one site of historic affinity were located immediately adjacent to the Tract boundary. The program initiated in 1974 recorded three more prehistoric sites, all within the Tract, and a number of isolated artifacts were collected.

The cultural materials indicate human occupation of the vicinity from about 5000 B. C. to the mid-twentieth century. The cultural resource is regarded as having scientific value in that the information present in some of the sites on the Tract may help to clarify our understanding of man's use of the Piceance Basin

over a period of several thousand years. None of the sites are deemed to have either national or regional significance when compared with other sites already recorded for the region. No nominations for the National Register of Historic Sites will be made from the inventory of Tract C-b sites. However, test excavations should be made at two of the prehistoric sites, 5RB136 and 5RB146 if they will be directly endangered by Tract development. If no direct disturbance of the sites is anticipated, the sites should be posted. No further action at the remaining three sites is necessary.

The state of present studies (C. H. Jennings and Spitzer 1976, Hurlbutt 1976, Olson et al. 1975, Weber et al. 1977) of prehistoric settlement patterns is still too immature to reach more than tentative conclusions. Nonetheless, we can hypothesize that the low site density on Tract C-b is partially the result of the generally northerly aspect of the Tract. Hurlbutt (1976) reported that for a sample of 127 sites, drawn primarily from the Yellow Creek drainage in the vicinity of Tract C-a, but including the sites known on Tract C-b, the dominant orientation of site exposure is to the south and southeast, those directions accounting for 41 percent of his sample. Only about 25 percent of the sites reported in Hurlbutt's study are oriented to the southwest, west, northwest, or north. Weber et al. (1977) report similar results for a sample of 89 sites though they take into account sites located on prominences and which are exposed to all directions. For the 68 sites with definite orientation the mean aspect is 184.7^0 with a standard deviation of 74.2^0. This range spans Hurlbutt's southern and southeastern aspect categories.

In addition to intentional avoidance of the locality on the grounds that it may have been rather cooler, because of its generally northerly orientation, the Tract is also generally unfavorably located in relation to water sources. While most of the Tract is no more distant from water sources than reported (Hurlbutt 1976, Weber et al. 1977), the permanent streams to the north, east, and west may have served to divert attention to locales in the vicinity where more desirable aspect characteristics were expressed.

Prior to the chaining of the Tract it must have possessed attractive vegetative resources. The game animal density in the area of the Tract has been disturbed by the chaining, but there would have been big game readily available to the prehistoric occupants of the locality. Informal comments have been offered by several observers in a variety of media concerning the relationships between site locations and present game animal distributions. The Tract, then, probably did hold at least some attraction to prehistoric people.

In a different dimension, chaining of the pinyon-juniper stands from much of the Tract has possibly negatively affected the site distribution. As the only sites found in the field examination are in unchained localities, it is reasonable to assume that chaining has destroyed at least some evidence of prehistoric occupation of the Tract. Unfortunately, the exact nature of the impact of chaining on archaeological sites is unknown, and we have no way of objectively evaluating the impact of the activity on our interpretation of the Tract's archaeological site intensity.

4.3.2 Purpose and Methodology

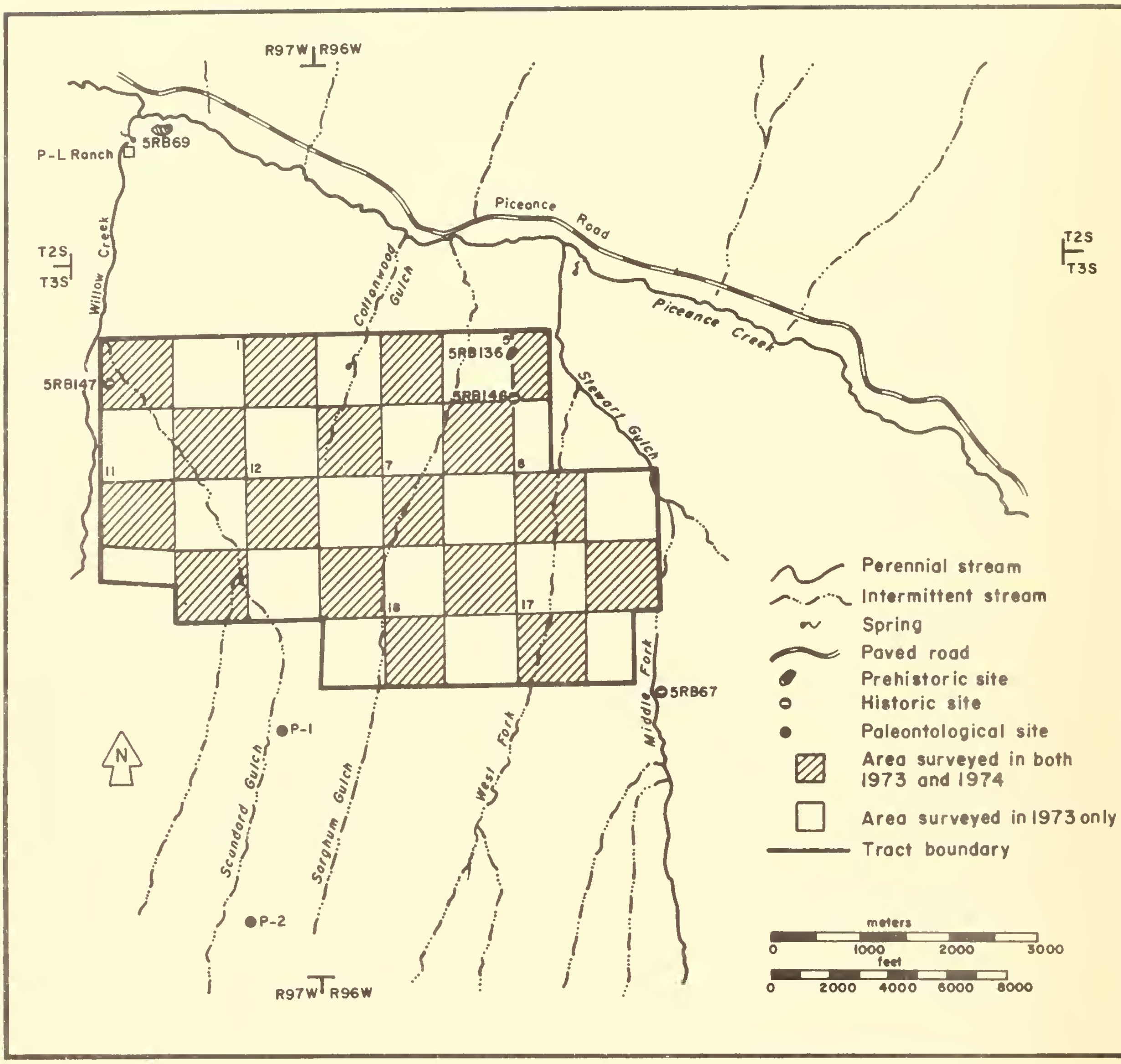
The purpose of the project was to identify sites of past human activity in the Tract environs, to relate them to contemporaneous activities in the region, and to assess the scientific value and historical significance of each site. This information is used by the Operator in preparing development plans so that valuable or significant resources are not lost but are instead preserved for future generations.

The field work was carried out from August 1 to August 11, 1974 under Federal Antiquities Permit 74-CO-055, issued through the Craig District of the Bureau of Land Management. A total of 56 man-days of effort were utilized and 2640 acres (52 percent of the Tract area) were intensively examined.

A quadrat system, utilizing quarters of public land survey sections as the sampling unit, was used for the field survey. The quadrats were laid out in a checkerboard pattern (Figure 4-2) rather than being randomly selected, on the premise that a more representative pattern of site distribution could be gained by use of the regularized distribution over the Tract.

The examining party of three or four began its coverage of the quarter-section at a section corner or a quarter-section marker and covered each of the quadrats in a series of sweeps made by walking abreast about 30 meters apart. This spacing, of course, varied with terrain and vegetation conditions. Areas with greater than 15 percent slope were not given intensive investigation, since previous surveys of similar slopes in the Piceance Basin have failed to yield any material of interest (sheet erosion would have removed anything that might have been there).

The three sites discovered were designated 5RB136, 5RB146, and 5RB147 in the Archaeological Survey of Colorado site inventory. Sites 5RB136 and 5RB146 are in the northeastern portion of the Tract and 5RB147 is in the northwestern corner (Figure 4-2). Surface collections were made without any attempt at systematization or standardization of area of coverage, since none of the sites had enough artifacts to warrant such procedures.



ARCHAEOLOGICAL AND PALEONTOLOGICAL SITES, TRACT C-b AND VICINITY

FIGURE 4-2

All the artifacts were catalogued in the Colorado State University system and are presently stored there. Analysis was limited to simple morphological description, since no single potential type was represented by more than a single specimen.

4.3.3 Other Archaeological Studies

The only other archaeological work performed in the Piceance Basin, prior to 1974, was carried out by Colorado State University (CSU) in cooperation with Thorne Ecological Institute of Boulder, Colorado. The project was part of the Regional Oil Shale Study for Colorado Department of Natural Resources (Thorne Ecological Institute 1974).

Two sites were recorded in this study in the vicinity of the Tract (Jennings 1974): 5RB67, in the Middle Fork of Stewart Gulch in the NE¼ of Section 21; and 5RB69, near the confluence of Willow Creek and Piceance Creek in the NW¼ of Section 36, T2S, R97W. No other sites have been recorded in the immediate vicinity of Tract C-b, owing in part to the lack of systematic archaeological reconnaissance in the area.

During the summer of 1974, activity increased in the Piceance Basin in response to the requirements for resource conservation associated with federal and state land management statutes. During 1974, field work continued on the Regional Oil Shale Survey, and the University of Denver and University of Southern Colorado also placed survey crews in the region. The University of Denver team worked under contract with the operators of the Oil Shale Tract C-a and concentrated its efforts in the Corral Gulch-Box Elder Gulch area of the Basin. The team from SCSC worked under contract in the area between Yellow Creek and Piceance Creek on the northern edge of the Piceance Basin.

4.3.4 Physical Environmental Background

To understand man's behavior, knowledge of the environment from which man extracted his raw materials and food, and continued his efforts for survival is necessary. Preindustrial man faced more immediate short-term environmental constraints than his modern counterpart. Because he had to be self-sufficient within a limited geographic area, intimate knowledge of the resources of each microenvironmental unit within his reach was mandatory. Failure to utilize the potential of any element of his environment might mean death or loss of the territory to some other group capable of exploiting the otherwise unrecognized potential.

This sensitivity to environmental constraints gives considerable value to physical environmental information as a tool for reconstruction of ancient man's activities. Consequently, no discussion of the archaeology of a locality is complete without an appreciation of the natural environment.

4.3.4.1 Topography

The topography of the Basin and the Tract are described in earlier sections. The general slope of the Tract is to the north, reducing, perhaps only slightly, its degree of insolation as compared with other areas which have higher site densities and generally southern exposures nearer the center of the Basin. The ridges and drainages alike would have provided easy routes of travel from Piceance Creek to the Roan Plateau on the south. East-west travel in this part of the Piceance Basin would have been most likely directed along Piceance Creek, but the ridges and shallow canyons south of the stream's course would certainly not have provided a major barrier to communication.

4.3.4.2 Geology

The geology of Tract C-b would have been of relatively little interest to the aboriginal users of the area, except for the uppermost element in the bedrock stratigraphy and the effects that the structure of the Basin and the permeability of the beds underlying the surface would have had on the availability of the surface water.

The uppermost member of the Basin's deposits, the buff to light brown sandstone and shale of the Uinta Formation, is of importance to the student of past human behavior in the study area because of its potential, or lack of it, for providing raw materials for tool manufacture. The sandstone is also important because of the nature of its weathering characteristics and the consequent unavailability of natural shelter in the region.

Sandstone cobbles from the Uinta were used as milling stones for pinyon nuts, acorns, and various grass seeds; there is some evidence of such use of the sandstone for these purposes. The substantial number of exposures of potential source materials for ground stone tools in the Piceance Basin have not, in fact, been intensively used as might be expected. The bulk of the handstones and grinding slabs are made on exotic materials rather than native sandstone. The relative softness of the stone and its tendency to wear rapidly may have made it a less desirable material for the preindustrial inhabitants of the region.

Materials suitable for stone tools are rare in the Uinta Formation. Consequently, the aboriginal users were forced either to trade for raw materials for arrowheads, scrapers, drills, and knives, or travel widely. A few amateur collectors have reported finding tools chipped from oil shale. These tools are very rare, and since oil shale is fairly resistant to weathering, it is suggested that rarity implies a lack of popularity and the lack of importance of the Parachute Creek exposures of oil shale in prehistoric times.

The lithology of the Uinta Formation is such that large rock shelters or caves were not available to the hunters and gatherers. Consequently, there is little likelihood of finding sites in the region that have the well-preserved perishables, such as leather goods, basketry, feather work; items that are usually found in rock shelters in areas with a similar climate. The presence of other sorts of natural shelter, such as prominent elevations and dense stands of trees, would have become a more important consideration in site selection in the absence of caves.

4.3.4.3 Hydrology

The hydrologic environment of the Tract C-b is one of the most important elements in prehistoric and early historic man's utilization of the region. The hydrologic situation in any area has potential for variation over time since springs can rise or dry up within a few years; streams dependent for their flow on springs must also fluctuate. Because of such variability, caution must be used in applying knowledge about present hydrologic conditions to the past, especially to the distant past.

In the immediate vicinity of the Tract are three drainages of potential prehistoric significance, i.e. Piceance Creek, Stewart Gulch, and Willow Creek (Figure 2-20). Observations made during the archaeological surveys on the Tract indicate that Willow Creek does flow year round, at least under the present climatic regime and water table conditions. The flow of water in Stewart Gulch seems much less stable. Surface flow has been observed in the Middle Fork near the southeastern corner of the Tract. To reconcile the archaeologist's casual observations with those of the professional hydrologist is beyond the scope of this study; however, these observations imply that, at least in recent years, surface water has been available on segments of Stewart Gulch and its middle fork and on Willow Creek. (Eds. note: Subsequent hydrologic investigations substantiated these observations and assumptions. See Section 2.3 on Hydrology.)

The map prepared by Coffin and his associates (1971) indicates the presence of springs near the mouth of Willow Creek, on

Willow Creek about 2 miles above the confluence with Scandard Gulch, on Cottonwood Gulch, and at the mouth of Stewart Gulch. These localities may have been occupied more regularly than areas more distant from water supplies.

Given more moist conditions in the region, one would expect that at least some, if not all, of the water sources described would have provided supplies of readily accessible surface water for early users of the Basin. However, these marginal water sources may have had relatively little value in the context of the larger, though seasonally highly variable flow in Piceance Creek located only about 900 meters north of the Tract (Meiman 1973). Domestic settlements may have been situated for the best access to Piceance Creek, given the constraints of shelter requirements and access to other critical resources. Piceance Creek gains in flow in the vicinity of Tract C-b (Coffin et al. 1971), indicating that perhaps even in periods of reduced precipitation the surface flow in the creek near the Tract was great enough to provide adequate water for the low population densities characteristic of preindustrial societies.

4.3.4.4 Climate

Climatic information for the Piceance Basin is limited. There is a series of records (1890-1974) from Rangely, about 36 air miles northwest of Tract C-b, and from Meeker, about 22 air miles to the northeast. There has been no long-term record kept in the Basin except at the Little Hills Game Experiment Station about 13 air miles north of the Tract, where records of daily maximum and minimum air temperatures have been kept since 1946. Precipitation figures from Little Hills show a mean annual precipitation of 12.90 inches (328 mm) for a 20-year period of record between 1951 and 1970; between a third and a half of the annual total is probably derived from snowfall (Marlatt 1973). Snowfall tends to be distributed fairly evenly over the region, though the actual amounts vary with elevation.

Two years of observation during the summer months leave the impression that the Tract C-b locality generally receives more precipitation than the Little Hills area. Whatever the actual numerical difference, annual precipitation at Tract C-b probably will not be above 15 inches (381 mm) on the average for any extended period of measurement.

Air temperature is somewhat more predictable. The Little Hills Station, for the 1951-1970 period of record, had an annual mean of 41.7^{0}F (5.90^{0}C). The roughly 400-foot (122-meter) difference in elevation between this station and the Tract C-b vicinity would account for a minor difference in air temperature.

The average seasonal extremes for Little Hills are 21.2°F (-5.9°C) in January and 65.8°F (18.8°C) in July (Marlatt 1973).

Climatic conditions are generally cool and semi-arid. The growing season for the area, estimating from Marlatt's study (1973), must be less than 100 days. The winters can be severe with long periods of low temperatures. The summers can be warm, but temperatures seldom go above 100°F (38°C). In general, the climate in the region is not severe enough to have limited human occupation, except, perhaps during the period from late or mid-December through February. The climate may, however, have had considerable impact on the kinds of subsistence activities pursued by the prehistoric inhabitants.

4.3.4.5 Soils

The soils of the region have been studied by Fox (1973); they are of interest to the archaeologist because of their impact on agriculture. Fox (1973) describes the soils as being predominantly cool to cold and calcareous or alkaline, except where there is coniferous vegetation and an acid condition exists on the surface.

Regional soil conditions are not suitable for most agricultural uses. The upland soils are thin and are too low in temperature. The alluvial soils along the drainages are warmer and permit the cultivation of alfalfa or timothy where adequate irrigation water is present. Generally, however, the area has a low agricultural potential.

4.3.4.6 Vegetation

The Tract vegetation represents a resource which must have been of great importance to the aboriginal users of the area. Some of the vegetation present in the Basin is of well-known economic importance in the aboriginal exploitative systems.

Tract C-b is represented mainly by pinyon-juniper, chained pinyon-juniper, big sagebrush, mixed shrub, and bunchgrass communities. The pinyon-juniper and mixed shrub communities are of the greatest interest because of their potential economic value to societies that subsisted by hunting and gathering.

The aboriginal situation is not easily reconstructed from what is seen in the present distribution of flora in the Tract area. The natural vegetation pattern has been recently disrupted by the destruction of large portions of the pinyon-juniper community on the ridge tops by chaining. These recent disturbances and the introduction of livestock have changed the vegetation of

the area to some extent. Also, human encroachment on mule deer ranges in areas such as the White River valley may have served to increase the deer populations in the Piceance Basin to anomalously high levels, thereby increasing grazing pressures on the plant communities.

The most reasonable statement that can be made concerning the plant resources of the Tract area is that the same species present now were quite likely present in the recent past. Though their proportionate representation cannot be reliably reconstructed from the presently available data, the availability of the resources can be determined.

The most important of these resources was most likely the pinyon crop. The nuts of the pinyon were widely exploited over the pinyon's entire range, and they still constitute an important resource to many American Indian groups. The nut is an excellent source of protein and provides 3250 kilocalories per pound in food energy. The pinyon crop provides a storable food source at a time of year when other resources are less abundant. Since the nut requires no complicated processing or elaborate equipment for its storage, it is readily available for the winter months when other food sources are restricted or nonexistent.

The serviceberry crop was also of some importance to the Indians of Colorado. The berry was eaten unprocessed or was pounded together with meat in a form of pemmican.

The pinyon and serviceberry crops would have provided at least some attraction for early man in the Piceance Basin. These plants are available on Tract C-b and vicinity and help to account for the presence of prehistoric sites in the locality. Because this attraction would have been seasonal, occupation of the area could have fluctuated accordingly.

4.3.4.7 Wildlife

Wildlife species in the Piceance Basin are abundant and highly varied (Cringan 1973). There are 82 species of mammals and 258 species of birds reported for the Piceance Basin; fish and other cold-blooded vertebrates appear in smaller numbers and with less variety.

The mammals include 27 species which would have been of value to preindustrial man. Horses were introduced to the Basin in relatively recent times and would not have provided a resource for any except for the most recent prehistoric inhabitants of the region. Even for these later inhabitants of the area, Tract C-b and vicinity would have held no interest with respect to wild horses, since the Tract is well outside the range of the wild

herds. Bison are less well understood. There was a herd present in the Basin as late as the summer of 1973. They had been introduced by the Colorado Division of Wildlife and were removed late in 1973 or early in 1974 after numerous complaints from local ranchers. Whether bison were present in the region prior to this time is not known. They provided good range for the introduced herd, and earlier bison would probably have done reasonably well in the area.

Aside from the bison and the wild horse, the rest of the economically significant mammals were all likely present in the Basin in prehistoric times and would have been accessible in the Tract C-b vicinity. Mule deer are extremely abundant now, and though the present numbers may be somewhat affected by the reduction of their former winter range outside the Basin, it seems likely that the ancient winter deer populations were comparable with those of the present. It has been widely reported that the Basin now supports the largest winter deer herd in North America. Elk also winter in the Basin, but their populations do not reach the magnitude of the deer populations.

Waterfowl, grouse, doves, and possibly even turkeys are also part of the economically significant fauna. Their numbers in prehistoric times cannot be easily reconstructed, but they were most likely part of the resource base for aboriginal man.

Faunal resources for Tract C-b and vicinity would have been adequate to permit at least seasonal if not year-round use by hunters and gatherers. None of the game animals noted by the biologists lend themselves to mass hunting except the hares and rabbits, and these only during periods of population explosion. Consequently, one would not expect to find use of the bluffs, canyon walls, or arroyos as jumps, pounds, or drives. Hunting in the region would have been based on individual rather than group effort and would not have encouraged the formation of large groups for any purpose except possibly rabbit drives.

4.3.4.8 Summary

This brief description of the environmental background of the Piceance Basin and Tract C-b vicinity indicates that there are no reasons why prehistoric man would have been prevented from occupying the region, and the Tract vicinity in particular. In fact, there are some elements in the area's environment which would have encouraged at least seasonal use of the Tract and the immediately adjacent areas.

Surface water seems to be available throughout the year, though there are considerable seasonal fluctuations. Raw materials for most kinds of stone tools are absent from the region, but wood

and various animal products are readily available now and probably were so in the past. The climatic regime, if similar to that of the present, would have placed a premium on shelter during the winter months. During other parts of the year people could have either done without shelter or made do with only the most rudimentary artificial windbreaks.

Dietary resources are varied and relatively plentiful at the present and in all probability were so in recent prehistoric times. The late summer and fall is now the period of greatest abundance and easiest procurement, and most likely was in the past as well. At that time of year the berry and pinyon crops are ripe and deer and elk move into the region from their summer ranges. Water supplies are most limited at that time of year but begin to increase in late fall; this may have been the major factor limiting human population density.

Generally, Tract C-b and its immediate vicinity are similar to other parts of the Colorado Plateau Physiographic Province. The Colorado Plateau has had a lengthy and varied history of human occupation. The resources of the Piceance Basin are nearly identical to those of such areas as the Coconino Plateau and the Defiance Plateau of northern Arizona. These two localities both supported occupation by humans at least as early as 2000 B.C. and were the scenes of the rise of two different cultural traditions. The oil shale country of Colorado, then, may also be a culturally rich area.

4.3.5 Paleontological Resources

Prior to this study it was believed that the Piceance Basin did not have any paleontological resources. However, geological field workers carrying out studies discovered mammalian fossils at two different places in the vicinity of Tract C-b (Figure 4-2). The fossils were forwarded to the Director of the University of Colorado Museum, Dr. Peter Robinson, who reported that one of the fossils is an as-yet-unidentified mammal and that the other is apparently the "head of a femur of a Uintathere, probably Uintatherium." More detailed studies are necessary before a definite identification can be made.

4.3.6 Synopsis of the Region's Cultures

4.3.6.1 Paleoindian Period: ? - 7000 B.C.

Man may have entered the New World as early as 30,000 years ago, near the end of the last glacial period of the Pleistocene. He was heavily reliant on hunting for his subsistence, with vege-

table products playing a relatively minor role. The animals hunted included many species now extinct, such as the Columbian mammoth and Bison antiques. Reliance on migratory herd animals placed a premium on community mobility, and the Paleoindians followed a nomadic way of life. The remains of their settlements are difficult to detect and, once located, are usually associated with the remains of their prey.

For all of western Colorado and the immediately adjacent portions of eastern Utah and southwestern Wyoming there are only five documented discoveries of artifacts or other remains which can be associated with this time period. The UP mammoth kill site in southern Wyoming (Irwin et al. 1962) indicates a possible Llano culture intrusion from the High Plains, but because none of the diagnostic Clovis points were found, the cultural affinities of the hunters are unclear. Also, several Folsom points have been reported from various parts of western Colorado (Bair et al. in preparation, Huscher 1939, Steward 1933, and Wormington 1955).

The absence of evidence of either proboscideans or bison in the Piceance Basin's fossil record indicates that the resources which would have attracted Paleoindians to the region were either not present or not present in large enough numbers to have met the hunter's subsistence requirements. There is no known evidence of Paleoindian occupation in the Tract C-b region and it seems unlikely that any indication of Paleoindian occupation will be found.

4.3.6.2 Archaic Period: 7000 B.C. - A.D. 1776

Climatic changes at the end of the Pleistocene reduced the range of the large animals and caused them to move northward. Along with the climatic and resource distribution changes, the human population of the New World was increasing. The resultant pressures placed an increased value on potential resources that had not been as intensively exploited during the preceding Paleoindian Period. Considerable generalization of subsistence activities took place, and items such as seed plants, various invertebrates, waterfowl, rodents, and the modern big game species took on increased importance in the subsistence base of the Archaic Period occupants of the continent. In each region of the New World, different resources were emphasized in the human diet, reflecting differences in availability. However, the pattern of exploitation was the same for all regions; intensive utilization of a wide variety of resources, usually following a seasonal round required a transient settlement system(Jennings 1957, 1964, 1974).

The sites of this period are easier to locate and produce larger inventories of artifacts than Paleoindian sites. The population of the New World was greater, with an increased number of sites, and sites were reoccupied seasonally over spans of hundreds, if not thousands, of years. Consequently, more information on the period exists, and for any given locality or region there is a greater probability that sites which date from the Archaic will be found. This is true of the Piceance Basin and the neighboring regions.

The earliest known occupation of the Piceance Basin probably occurred at sites 5RB13 (Jennings 1974) on Tract C-a and 5RB3985 (Weber et al. 1977) which is located about five miles southwest of Tract C-b. Both sites have produced fragments of large bifaces which have been parallel flaked. The 5RB13 specimen, in addition, has been heavily polished along both lateral margins to a distance of about 1.75 cm above the polished base. These points are members of a class that have been found in various parts of the western United States. The nearest site outside the Basin which produced such points is Deluge Shelter in Dinosaur National Monument (Leach 1967, 1970a). The earliest occupation levels at the site are estimated to date from 7000 B.C. Breternitz (1970) sees this as the initial Archaic occupation in northeastern Utah and northwestern Colorado.

Following the earliest Archaic Period, the intensity of occupation increased steadily over the next several thousand years. Sites dating from after 5000 B.C. are numerous both south and north of the Piceance Basin (Breternitz 1970, Buckles 1971, Day 1964, Lister 1951, Wormington and Lister 1956). Sites of this antiquity have also been found in various parts of the Piceance Basin, and there is some indication of the utilization of Tract C-b during this and later periods.

The Archaic Period has been extended to A.D. 1776, as there is no evidence of the pursuit of any other life style in the Piceance Basin before the first written documentation of the region's inhabitants.

In the neighboring regions a mixed horticultural and foraging subsistence system was followed in prehistoric times. This system and its associated cultural items have been gathered under the title of Fremont Culture. The items include, for example, cultivation of maize, a characteristic gray pottery occurring in a number of regional variants, masonry granaries, shallow pit houses, dry-laid masonry "forts," and rock art typified by horned, trapezoidal-bodied, shield-bearing anthropomorphs. Their chipped stone tools have not been studied in great enough detail to permit objective separation of such items as Fremont projectile points from those made by other contemporaneous peoples who occupied neighboring regions. The Fremont lifestyle was practiced in

Utah and northwestern Colorado at least between A.D. 900 and 1200 but may have appeared as early as A.D. 700 (Aikens 1970, Breternitz 1970, Gunnerson 1969, and Wormington 1955).

For the Piceance Basin, definite evidence of Fremont occupation is limited to pottery (Olson et al. 1975, Weber et al. 1977). Mr. James Grady has personally reported the presence of what he deems are prehistoric agricultural fields on Piceance Creek a short distance upstream of the site of the Square S Ranch. His data consist of a rock shelter and regularly occurring features, visible in aerial photographs, on an alluvial fan near one of the rarely occurring rock art sites in the Basin. There are <u>no</u> sites known which have any definite Fremont architectural features.

The projectile points that have been found in Fremont sites in Dinosaur National Monument have morphological similarities with some types found in the Piceance Basin. As noted above, however, these similarities are not regarded as diagnostic of the Fremont. The grounds for this position rest with the fact that lithic technology is rigidly constrained by its raw material. Narrow restrictions are imposed on the possible variety that can be expressed in the system. The similar styles of projectile points which occur in the Piceance Basin and other parts of what was formerly Fremont territory can be attributed as easily to such constraints as to a common cultural origin.

In light of the currently available information, the only reasonable interpretation argues that the Fremont, probably people from Douglas Creek (Wenger 1956) which is immediately west of the Basin, were the principal exploiters of the Basin's resources. They most likely crossed the Cathedral Bluffs in order to tap the big game and pinyon crops and came as hunters and gatherers with tools and site selection criteria which would have been indistinguishable from those of other foragers. Consequently, the Fremont occupation of the Basin is irretrievably intertwined with the Archaic use of the Basin.

The failure of the Fremont to exploit the region at a horticultural level can most reasonably be attributed to the same causes which have limited agricultural activity in the Basin in modern times. The cool to cold soils and short growing season are no doubt the principal restrictive factors. Because of the climate, corn cultivation would have been a highly unreliable source of subsistence.

The pursuit of the generalized hunting and gathering pattern is seen as extending to the time that the first written records were made concerning the people of the Piceance Basin and its neighboring regions. No change occurred in A.D. 1776 insofar as the aboriginal inhabitants of the region are concerned;

they were simply identified by Europeans in such a way that we associate them with the ethnographically known groups inhabiting the region in later times.

4.3.6.3 Protohistoric Period: A.D. 1776 - A.D. 1868

In 1776 the Spanish priest, Escalante, crossed western Colorado on his attempted journey to California and encountered bands of Indians whom he identified as Yutas (Bolton 1950). He did not pass directly through the Piceance Creek basin, as his route took him over the Roan Plateau and down Douglas Creek to the White River. Although no Indians were encountered, he had been told that a band, related to the Yutas he had encountered farther south, did inhabit the region. The Escalante-Dominquez expedition gives the first evidence of the use of the region surrounding Tract C-b by an enthnographic group, the Utes.

In the Piceance Basin, several sites have been located which may be the remains of the Ute occupation of the region. There are about 20 of this type of site, e.g., occurring along the major drainages in the northwestern quadrant of the Basin. They have an artifactual content which in some cases lacks both pottery and Euro-American goods; in others there is native earthenware but not historic materials; at others pottery, stone tools, and trade beads have been found; yet in others aboriginal architecture in association <u>only</u> with artifacts of Euro-American origin, such as late 19th century tin cans has been found. The dominant characteristic of all of these sites is their architecture. All have wickiups, a simple shelter made by leaning logs against a living tree and then covering the frame with branches. The interiors frequently have shredded juniper bark floors. One site also has a circular dry-laid masonry feature which may have served as a corral (Weber et al. 1977).

These sites, including the Duck Creek Wickiup Village which is on the National Register of Historic Places, were most likely used by the Protohistoric and Historic Period Ute during their tours of the Basin. They most certainly constitute a continuous record of acculturation and changing man-environment relationships.

No evidence of the sites described above were found in Tract C-b. The sites located on and near the Tract are either definitely tied to the Euro-American occupation of the area or show no clear ethnographic relationships.

4.3.6.4 Euro-American Period: A.D. 1868 - Present

4.3.6.4.1 Ute Indian Agency and Meeker, Colorado

The first White River Ute Agency was established near the present town of Meeker, Colorado in 1868. The Agency was run in the usual fashion of the late nineteenth century in that there was relatively little interference with Indian daily life, so long as the Indians created no difficulty for the Euro-Americans moving into the region.

In 1878 the White River Agency was placed under the direction of Nathan C. Meeker who, through ignorance and well-intentioned paternalistic blundering, created an extremely volatile situation with the Utes residing in his area of responsibility (Brown 1972, Emmitt 1954, Hafen 1933, Sprague 1958). The result of the situation was the massacre of the Agency's male personnel and the death of several members of a military expeditionary force which Meeker had called for to assist him in meeting the crisis (Brown 1972, Hafen 1933, Sprague 1958).

The White River band of Utes were removed from the Meeker district following the 1879 uprising. They were placed on a reservation with the Uinta band and access to their ancestral lands was denied them. However, occupants of the White River region and the Piceance Basin have told stories about the Utes continuing to hunt and to gather in the area into the early 1900s.

4.3.6.4.2 Trail Herds, Railroads, and Mining

The last half of the nineteenth century was a time when many divergent developments were brought together, linked primarily by transportation, particularly, the railroads. The opening of the area to the trail herds officially began with the withdrawal of the army troops from Meeker in September 1883. Rangely, Meeker, and Rifle soon profited as ranch supply towns. The vast trail herds of grass-fed cattle left a distinctive mark on the history of the area. Beginning in 1884 cattle were trailed in great numbers into the Piceance Basin, coming not only from Texas but also from Arizona, the plains of eastern Colorado, the Laramie plains in Wyoming, and by the thousands from Utah. During the summers they grazed on the high Roan Plateau and the Book Cliffs. In the fall they were rounded up along the Piceance Creek for drives to Rifle.

As an example of the impact of the cattle on the area, records show that a cattleman named Jim Rector took charge of the combined operations of three trail herds in 1888 totalling 23,000 head. They grazed from the Utah state border on the west to as far east as the top of the Book Cliffs at Rifle. A round-up involved as many as 60 cowboys over a month or more and literally covered tens of thousands of square miles. The cattle were driven in six or seven separate herds to the rail head.

In addition to the vast numbers of cattle, extensive Indian horse herds were left behind in Colorado at the time of the Ute removal in 1881. Thousands of horses also freely roamed the Basin, competing with the cattle, and later sheep, for the grass. While modern domestic livestock use of grasses in the area is controlled, overgrazing by cattle and horses during the trail herd era created a 400 to 500 percent range overloading.

During the trail herd era, the oil shale area became a major source of feed supply to the booming coal mine towns, and the Piceance Basin enjoyed brief importance as the most direct access route for livestock drives from Rio Blanco County to the slaughter-houses of Leadville and Aspen. The cross basin drives later ended with the completion of a road north from Rifle to Meeker.

However important the trail herds were in developing the area, the mining era vastly accelerated construction of the major rail lines as well as numerous spur lines. After the Leadville silver discoveries, the 1877 mining boom impact was felt more directly in the oil shale territory. It was then that the clamor for railroads to tie the supply and market towns of the region together with the rest of the country became an irresistible public demand. Railroads were needed to get supplies shipped in and products shipped out. The construction of the railroads in turn provided the impetus for an additional influx of cattlemen and miners.

4.3.6.4.3 Homesteading

The expulsion of the Utes from the Piceance Basin and surrounding areas precipitated a land rush in the early 1880s, which in turn, led to the formation of Garfield County and later Rio Blanco County (Hafen 1933). Homesteading in the Piceance Basin was limited primarily to the areas along the major drainages which had either surface water flow or easily accessible ground water. The homesteading activity led to the founding of a local school district and the construction of a number of school buildings in various parts of the Basin. Perhaps the best known of these is the Rock School, which was built in 1897 and subsequently modified by various remodelings and additions. The Rock School is of interest because of the use of oil shale for masonry material.

During the early part of the twentieth century the fortunes of the homesteaders in the Piceance rose and fell, but the end of the homesteading era came with the economic collapse of the 1930s. Many of the homesteads were abandoned while others, with perhaps more economic potential, were purchased by the more successful ranchers and were incorporated into their land and cattle operations. These operations, some of which are still active, were dependent

upon the combination of access to extensive tracts of unimproved range through the various federal leasing programs and on the supplementation of range feed with hay grown in the privately owned irrigated meadows along the better drainages. These practices continue to the present time.

4.3.6.4.4 Early Towns

Meeker was the first incorporated town in northwestern Colorado. The present town site of Meeker is where General Wesley Meritt, Commander of the expedition to quell the Ute uprising, hurriedly built a military camp in 1885. Laid out as a typical army presidio, it had nine adobe barracks on the south side of its parade ground (now Court House Square) and the officers' quarters on the north. Several of these buildings are still in use.

Meeker served for some time as a banking and credit center for all the range country between Grand Junction and Rawlins. Perhaps one indication of Meeker's early prominence was that in October 1896 three robbers, thought to be part of the Butch Cassidy gang, held up the town bank. Townspeople shot the trio dead in the streets as they tried to make a getaway with $1,600 in cash.

Meeker's commerce was augmented considerably by tourist income which was magnetized by President Theodore Roosevelt's nationally publicized hunting trips into the Flat Tops area east of Meeker. The area had also gained social prestige even earlier when titled English gentry formed several local polo teams during extended trips. Ute trade also continued to be substantial and their deerskins were a major item for the trading posts at both Meeker and Rangely. Although the Indians were formerly confined to the Utah reservation, many bands kept permanent camps in the western part of Colorado.

To the west of Meeker was White River City at the confluence of the White River and Piceance Creek. Never formerly organized, and scarcely more than platted, it consisted of eight to ten primitive buildings that were eventually left to rot in the early 1900s. John Hugus had founded it in 1878 while still the post trader at Fort Steele near Rawlins, Wyoming. Hugus anticipated the routing of the Colorado - Midland Railroad from Rifle up Piceance Creek enroute to Salt Lake City. Railroad survey parties did reach this town but the line was never built beyond Newcastle. When the Hugus business was moved to Meeker, White River City was abandoned.

At what is now Rangely, a trading post had been established shortly after Congress ratified the Ute Treaty of 1880, nearly a

year before the Indian's removal in September 1881. Under terms of this treaty, the Utes thought they were to be permitted the continued use of their hunting grounds in Colorado. In 1885, however, the Supreme Court ruled that Indians off the reservation were subject to state laws and, by this time, all hunting in Colorado had become licensed. Even so, with Rangely so close to the Uinta Reservation boundary, the general store continued to enjoy a thriving Ute trade for many more years. After the Utes were finally confined to the Utah Reservation, the trading post became a neighborhood ranch supply center, primarily because of its convenient location at the confluence of Douglas Creek and White River.

About 22 miles south of Meeker is the Rio Blanco Store, situated at the intersection of Piceance Creek and Government Road (now State Highway #13) from Meeker to Rifle. Rio Blanco was apparently started by the Harper brothers of Meeker as a stop for their freight and stage service. They also upgraded the primitive north-south trail road and built a series of bridges. Eventually the state took over maintenance and improvement of the route.

The town of Rifle, with its road network to the north, east, and west was similar to Glenwood Springs in being a hub-town and was locally known as a "Saturday Night" town. Rifle's trade area extended north into Rio Blanco County as well as to the fruitland mesas lying in the fertile valleys to the south.

To the west of Rifle, along the valley formed by the Colorado River 2,000 feet below the rugged cliffs of the Roan Plateau, are the two small towns of Grand Valley and Debeque. Debeque was originally established as another range livestock center in 1882 while, from its inception, Grand Valley aimed at diversification through orchard and vegetable crops. Since 1890 Grand Valley had also been noted as the center of the Piceance Basin's oil shale interest.

Six years after Dr. W. A. E. Debeque located his ranch headquarters at the mouth of the Roan Creek in 1883, the town site of Debeque was platted by the Curtis Town and Land Company. The platting came shortly after the arrival of construction crews building the Denver, Rio Grande, and Western railroads through Grand Junction. Debeque was incorporated as a town the following year.

4.3.6.4.5 Recent Community Development

The three county region of Rio Blanco, Garfield, and Mesa Counties is still largely rural in spite of the long-term trend of population growth, increasing tourism, and expanding residential

and second-home development. In 1970 urban settlement occupied only about 3 percent of the land in Rio Blanco County, 13 percent in Garfield County, and 28 percent in Mesa County. Only 16 percent of the land in the region as a whole is devoted to urban development. Relatively little strip development disturbs the countryside, and suburban development has largely been concentrated in the larger municipalities such as Grand Junction and Glenwood Springs.

Urban settlements originated largely as agricultural trading and banking centers and occasionally as support centers for major oil or mining activity. The major towns in Garfield and Mesa counties are along the east-west highway, Interstate 70, which runs through Grand Junction on the west and Glenwood Springs on the east, paralleling the Colorado River. In Rio Blanco County, the major towns of Meeker and Rangely are located on the highway which runs north from Rifle to Meeker and then west from Meeker to Rangely along the Basin's northern edge.

4.3.6.4.6 Demographic Characteristics

In 1975 available population estimates show that Garfield and Mesa Counties were growing at an estimated annual rate of 2.85 percent and 1.30 percent, respectively (C-b Shale Oil Project 1976). The population in Rio Blanco County was estimated to be increasing at an annual rate of 1.84 percent, reversing its population decline during the 60's. The three county region is expected to continue growing at a rate of about 2 percent a year without growth induced by rapid industrialization. The region is still highly rural. About 52 percent of the population of Mesa County and 72 percent of Garfield County in 1970 were living in rural areas. Rio Blanco County has no urban areas by census definition.

By 1970 Meeker had 33 percent of the population of Rio Blanco County with 1,597 people and Rifle had about 15 percent of the population in Garfield County with 2,150. Based on these estimates, Meeker had grown approximately 35 percent between 1970 and 1975; Rifle had grown about 28 percent during that same period.

Little ethnic diversity exists in the three counties. They are predominantly white, although approximately 1 percent of Mesa County's residents were Spanish-American in 1970. Slightly over 50 percent of the residents of the three counties were born in Colorado and the median age of persons in the three counties in 1970 ranged from 26.9 in Rio Blanco County to 30.0 in Garfield County and 30.2 in Mesa County.

The educational level for the region in 1970 was close to the state average in median school years completed. Residents of the state as a whole had a median of 12.4 school years completed as compared with the three county average of 12.3 median school years

completed. All three counties in the state grew faster from immigration than from natural increase in 1974.

There is a significant variation in total population between Garfield, Mesa, and Rio Blanco Counties, although they are very similar in terms of total land area. Mesa County encompassed 3,303 square miles as compared to 3,263 for Rio Blanco County and 2,997 for Garfield County. The population density, measured in terms of the number of residents per square mile, varied from a high of 16.5 in Mesa County to 4.9 in Garfield County, and 1.5 in Rio Blanco County in 1970. The concentration of persons per square mile increased in Mesa and Garfield Counties between the period 1960 to 1970 while the concentration in Rio Blanco County decreased.

The three county area was still largely rural in 1970 and even the high estimates of population in 1975 did not significantly change its rural character. For example, Grand Junction had only 37.1 percent of Mesa County's population in 1970. The proportion of persons living in towns in the three counties remained fairly constant between 1960 and 1970. Meeker, for example, had only 9 percent more of Rio Blanco's population in 1970, while Rifle had 3.3 percent less of Garfield County's population.

4.3.6.4.7 The Regional Economy

The economy of the three county region is primarily based on agriculture and tourism. However, agriculture has declined as the most important source of income in this region over the past several years. Tourism and public services such as education have grown in Garfield County. Mesa County has experienced growth in manufacturing and in public services. Rio Blanco County has shown increases in trade and in public services. The labor participation rate has increased in Mesa and Garfield counties but has recently declined in Rio Blanco County. Increases in the labor participation rate are partly attributable to newly opened fields such as education and health, in which job opportunities are opening up for women. This has contributed to the increase in percentage of households with more than one person working.

The decline in Rio Blanco County's labor participation rate between 1970 and 1974 is probably because of the general increase in unemployment in that county. Also, heads of households employed in traditional areas appeared to be shifting occupations to meet the new employment opportunities that are available in the region. The employment supply situation does not seem to provide many opportunities for other members of households to fill positions. Otherwise, unemployment has generally decreased between 1970 and 1975 in Garfield and Mesa Counties as it has in the State of Colorado.

Median family income, as a percentage of the state's average, has declined in all three counties between 1960 and 1970. Rio Blanco County has experienced a major decline in this indicator from 111 percent in 1950 to 83 percent in 1970. The three counties are approximately equal to the State of Colorado in the percentage of families below the poverty level. Garfield County had 8.4 percent of its families living below the poverty level in 1970, whereas the figures for Mesa County, Rio Blanco County, and the State are 11.4 percent, 10.1 percent, and 9.1 percent, respectively. Regional retail sales increased substantially in dollars between 1960 and 1974. This rise reflects growth in the tourist and services sectors, especially in Garfield and Mesa Counties.

If positive economic trends continue within the three counties, trade, private services, and public services will be increasingly important areas of employment. Some growth will occur in the mining, manufacturing, and construction industries. However, agriculture is expected to continue to decline.

4.3.7 Summary

The Piceance Basin has been the scene of human activity since about 7000 B. C., at the very earliest. Between this early date and A. D. 1879, the area was utilized by various groups of American Indians, who hunted the game of the region and gathered the fruits of its varied flora. None of the groups occupying the region at this time left any definite indication that they attempted any sort of farming. The last occupants of the region were the Ute Indians, who were in the area at least as early as 1776 and who remained there until forcibly removed in 1879.

Upon the expulsion of the Utes from the Piceance Basin, Euro-American settlers began to occupy the area. The early settlers raised sheep and cattle in the Basin, and the subsequent overgrazing had considerable effect on the landscape. Interest in the minerals underlying the Basin fluctuated during the twentieth century but has never led to any extensive utilization plans until the present time.

The three county region of the Piceance Creek basin had had a varied history. From the early nomadic Utes to more recent agriculture and mining interests, the area has been oriented to numerous land uses. As the region grows, it is gaining more and more of an urban character, although much of it is still rural. The employment base of the counties is shifting and diversifying. The population of the entire area is growing rapidly, reversing previous trends. Future changes will likely bring increased economic activity and certain alterations in the traditional rural way of life that the people of the region have known for decades.

The role that the Tract C-b area played in the cultural history of the region is not entirely clear. Prior to the discovery of the sites described above, there was no evidence that the Tract area played any role in the regional history whatsoever. What is clear is that the aboriginal occupants of the Piceance Basin did include the Tract vicinity in the territory they saw fit to occupy and utilize.

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APPENDIX

A.1 Introduction to Dendrochronology and Dendroclimatology

Dendrochronology may be defined as the science of measuring time intervals and dating events and environmental changes by reading and dating growth layers of woody plants as demarcated by annual rings. This study in the Tract C-b area is intended to produce a master chronology that dates the growth increments of pinyon pine (Pinus edulis) for the area and to use climatic information and dated growth layers to study variations in past and present climates.

The width of growth rings can serve as natural records of climatic variation when they vary as a function of some limiting environmental factor (Douglas 1919). In semi-arid western Colorado that limiting factor is precipitation (Schulman 1945). Not all woody plants produce growth-layer sequences that are datable and useable for climatic inference. The shrub species do not preserve a ring-sequence record of sufficient length for dendroclimatology and often the rings are not clearly recognizable. Utah juniper (Juniperus osteosperma), the codominant with pinyon pine (Pinus edulis) on Tract C-b, often produces several growth layers per year making it unsuitable material. Douglas fir (Pseudotsuga menziesii) would be useful material if it were present in the area in larger numbers and in locations demonstrating greater water stress. On the other hand, pinyon pine is present throughout the area and in sites receiving only superficial runoff. Also, it has a sufficiently long tree-ring sequence to make it acceptable for dendrochronologic and dendroclimatic studies.

A.2 Methodology

Three sampling sites were chosen within the study boundaries of Tract C-b (Figure A-1). Each site was a stand consisting of pinyon-pine trees. Four cores were taken from each tree four and one-half feet above the ground (Diameter at Breast Height). The cores were dried in redwood boxes for 10-14 days and then mounted in wooden slats. The cores were prepared for examination by sanding with various grades of sandpaper. Number plots and skeleton plots were constructed for each core using the methods detailed by Glock (1937).

A total of 32 trees were sampled in this study. Twenty-nine trees were used in building the master chronology. Three trees were not included in the master chronology because their growth layers were severely distorted. The growth increments listed in the master chronology (Figure A-2) are indicated by vertical lines (diagnostic growth increments). Diagnostic growth increments are growth layers or rings which are either extremely narrow or extremely wide. The direct response of tree-diameter growth to precipitation allows the use of this diagnostic tool. In years when precipitation is high, ring width increases dramatically; similarly, ring growth is narrow in years of low precipitation. Since all tree growth responds roughly equal to precipitation, it is possible to identify and correlate these diagnostic increments between individual trees and to assign a date to them.

These vertical lines represent the relative thinness of that growth increment. The height of the line is inversely proportional to the relative thinness of the growth increment, in relation to its neighbors. Both the height and interval between diagnostic growth layers are important in using a chronology, identifying missing rings and cross-dating.

Following completion of the master chronology, the dated growth increments were measured to 0.01 millimeter with a standardized ocular micrometer. The mean width of each annual increment was calculated for each tree using the four cones taken per tree and plotted graphically against age.

The mean tree-ring measurements for each tree were converted to standardized indices and averaged to obtain a ring-width chronology that is likely to correspond to short-term growth-limiting fluctuations in climate (Fritts 1971).

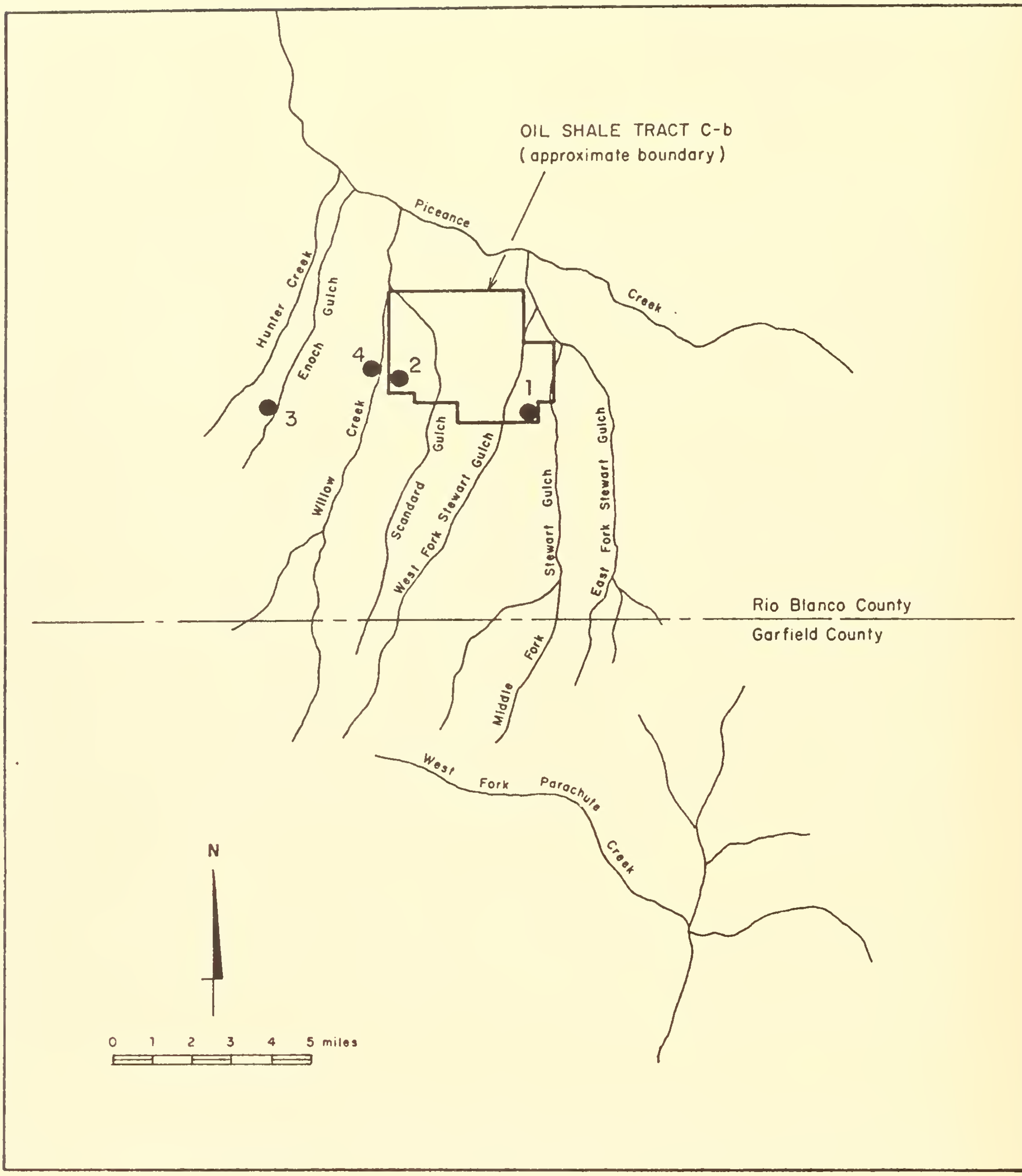

Figure A-1

STAND LOCATIONS FOR THE DENDROCHRONOLOGIC AND DENDROCLIMATIC STUDY

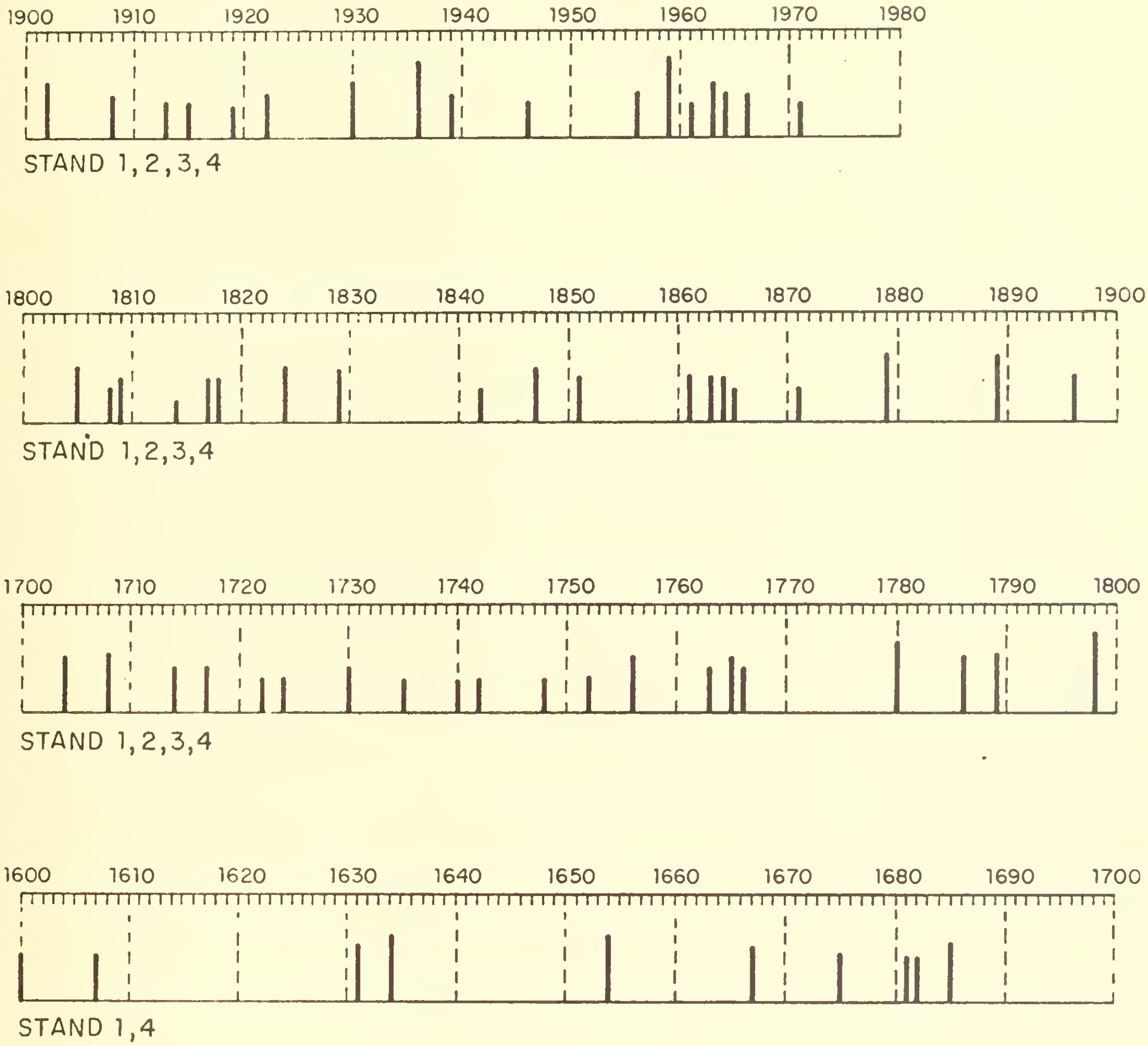

Figure A-2

MASTER STAND CHRONOLOGIES

The standardized indices for each tree were compared with the October-through-June precipitation record from the towns of Meeker and Rifle, Colorado, using Spearman's rank correlation coefficient. It was necessary to correlate the variation in tree growth with precipitation, to establish if the precipitation regime has been a limiting factor in the Tract C-b study area and to establish which trees did or did not reflect this correlation. Twenty-nine trees were used in the correlation.

The dendroclimatic analysis consisted of two phases: modeling and interpretation. Modeling, using both multiple and linear regression was necessary to predict the past climatic changes knowing only the variations in standardized tree-ring widths. The multiple regression analysis compared standardized tree growth for each year with three independent variables: October-through-June precipitation for each year of growth, October-through-June precipitation for the previous year, and the previous year's standardized growth for each tree. An analysis of variance was performed on each regression and an F-value was calculated. Two trees were eliminated from the final multiple regression analysis: one, because its F-value was below the 95 percent level of confidence and the second, because its partial regression coefficients differed markedly from the other calculated coefficients.

The standardized, tree-ring indices for the remaining trees were averaged for each year and a multiple regression of mean standardized tree growth for each year was performed. The independent variables were: October-through-June precipitation for each year of growth (x_3), October-through-June precipitation for the previous year (x_2) and the previous year's mean standardized growth for all trees (x_1). An analysis of variance was performed and an F-value was calculated.

The final multiple regression equation, $y_{est} = 0.45x_1 + 0.044x_2 + 0.011x_3 + 1.03$, was used to calculate the past climatic regimes (y_{est} using the known precipitation record from Meeker, Colorado) and the tree-ring record extending back to 1437 A.D. The multiple regression model, though statistically significant, did not adequately predict known precipitation values so a linear regression model was constructed, based on 18 trees (11 of the original 29 trees were eliminated from the model; the ages of these trees were less than 250 years and did not meet the requirements of the model), using mean standardized tree growth for each year (y) and October-through-June precipitation for each year of growth (x) (Figure A-3). These values are graphed in Figures A-4 through A-9.

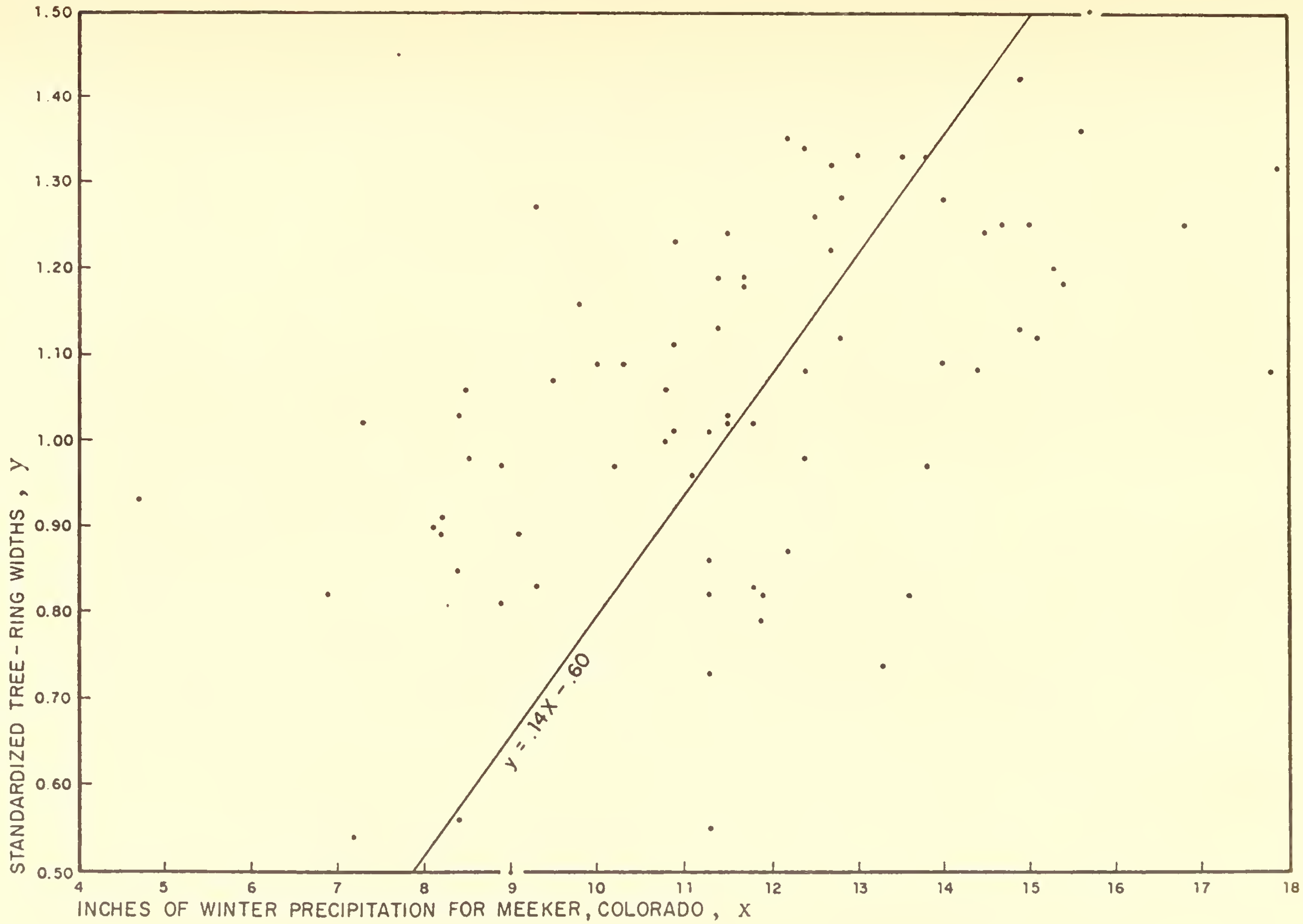

Figure A-3

SCATTER DIAGRAM AND LINEAR REGRESSION OF
RING-WIDTHS AND WINTER PRECIPITATION

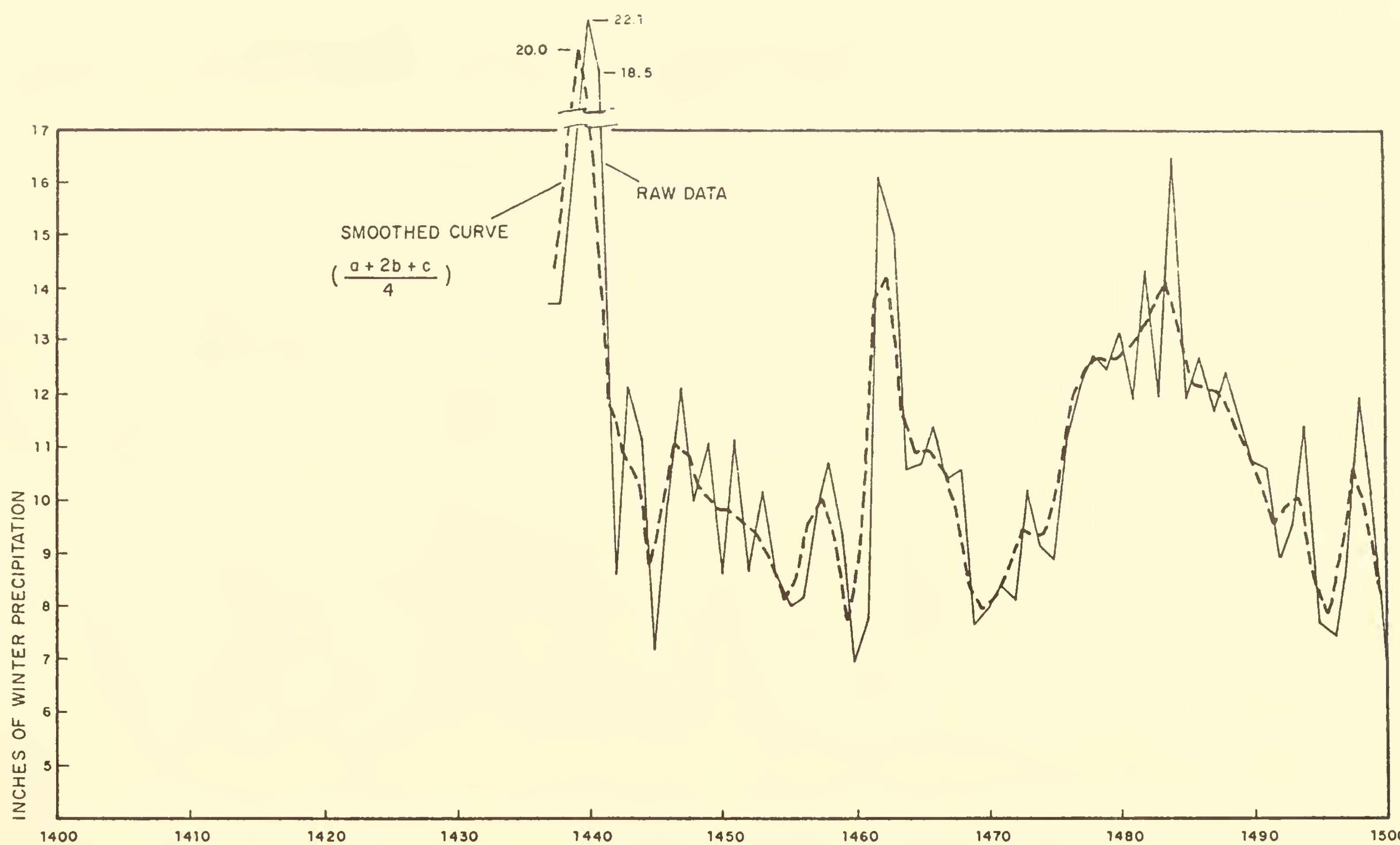

Figure A-4

PREDICTED WINTER PRECIPITATION REGIME USING THE LINEAR REGRESSION MODEL, 1400-1500

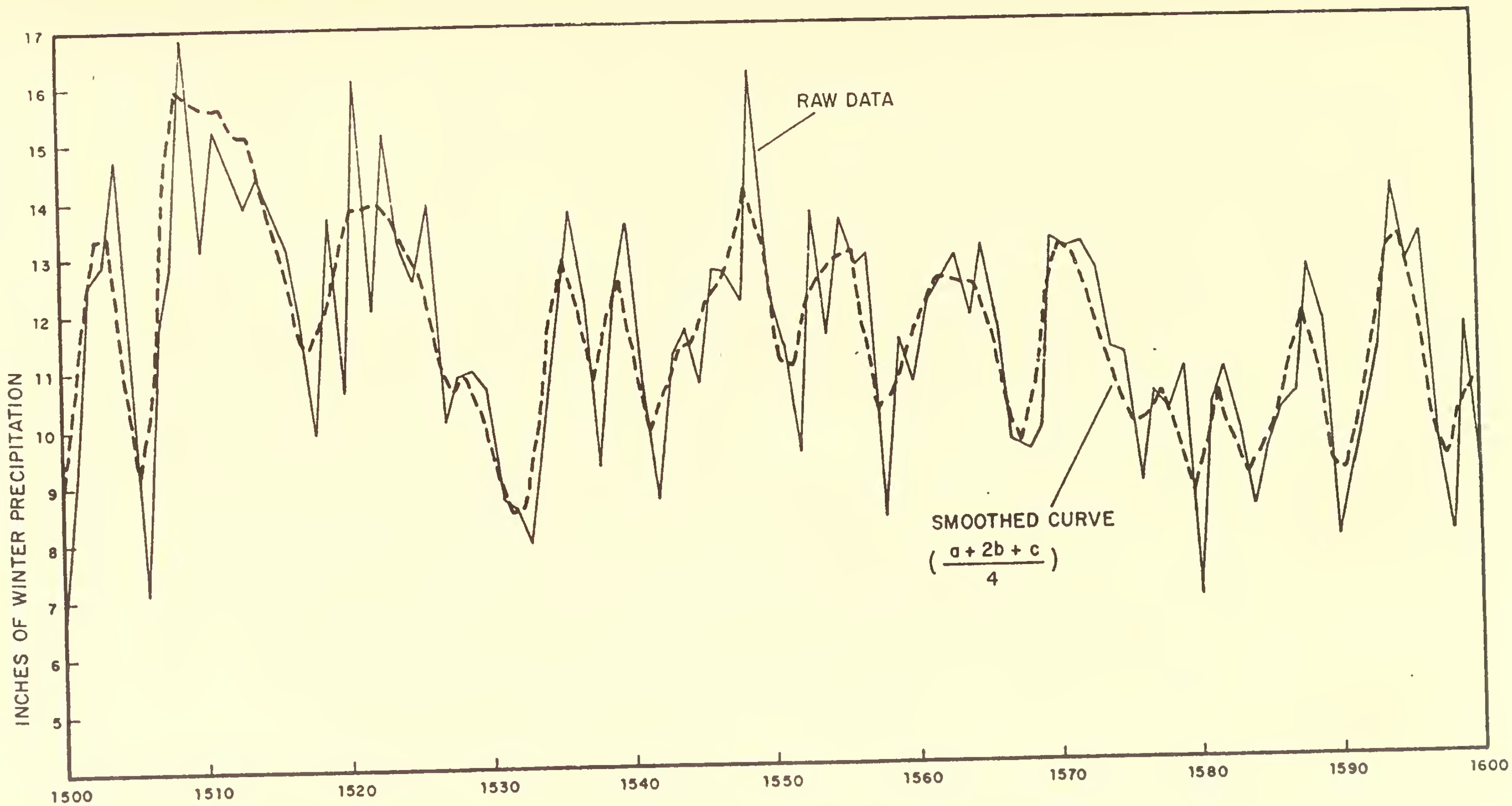

Figure A-5

PREDICTED WINTER PRECIPITATION REGIME USING THE LINEAR REGRESSION MODEL, 1500-1600

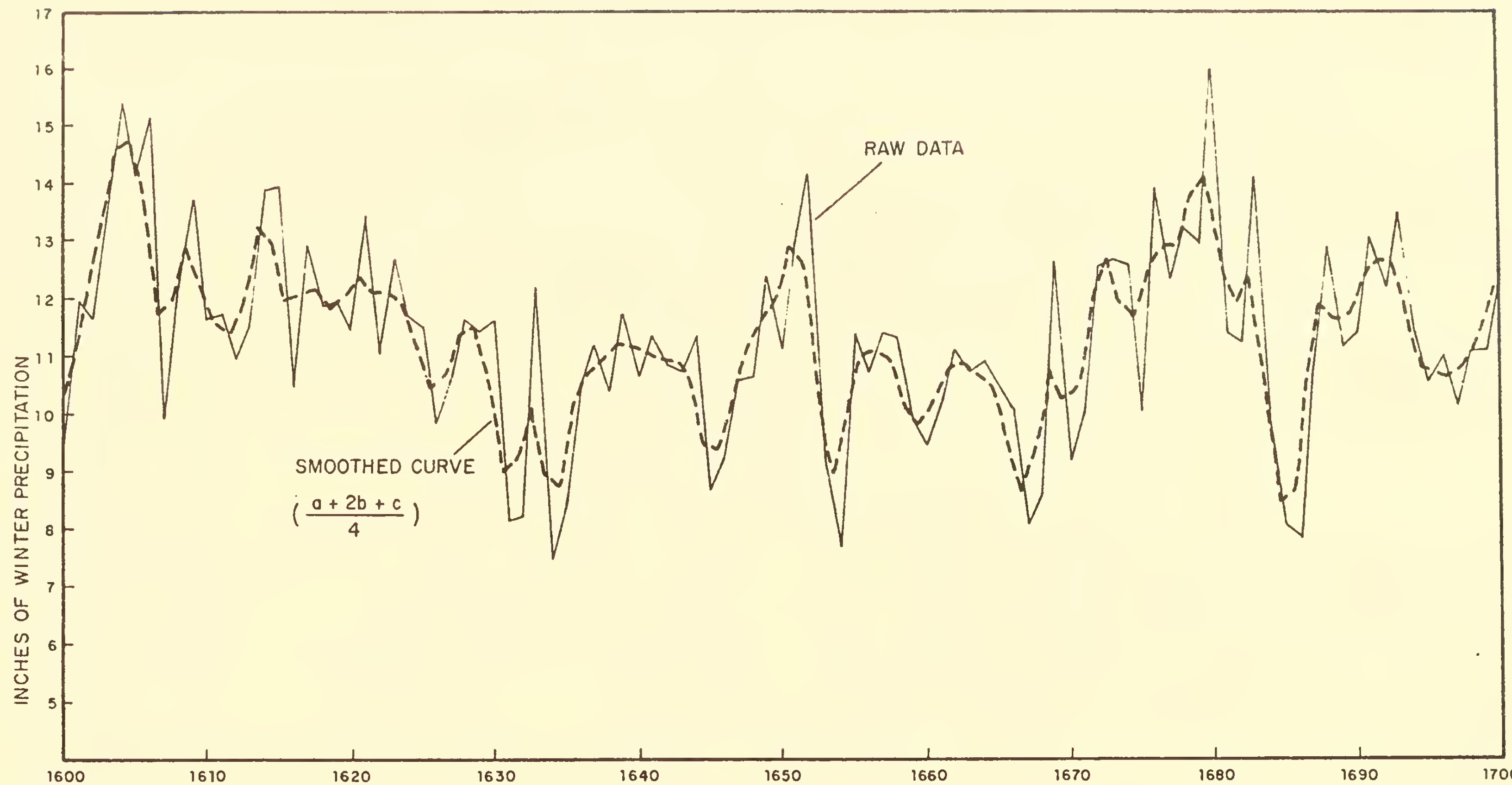

Figure A-6

PREDICTED WINTER PRECIPITATION REGIME USING THE LINEAR REGRESSION MODEL, 1600-1700

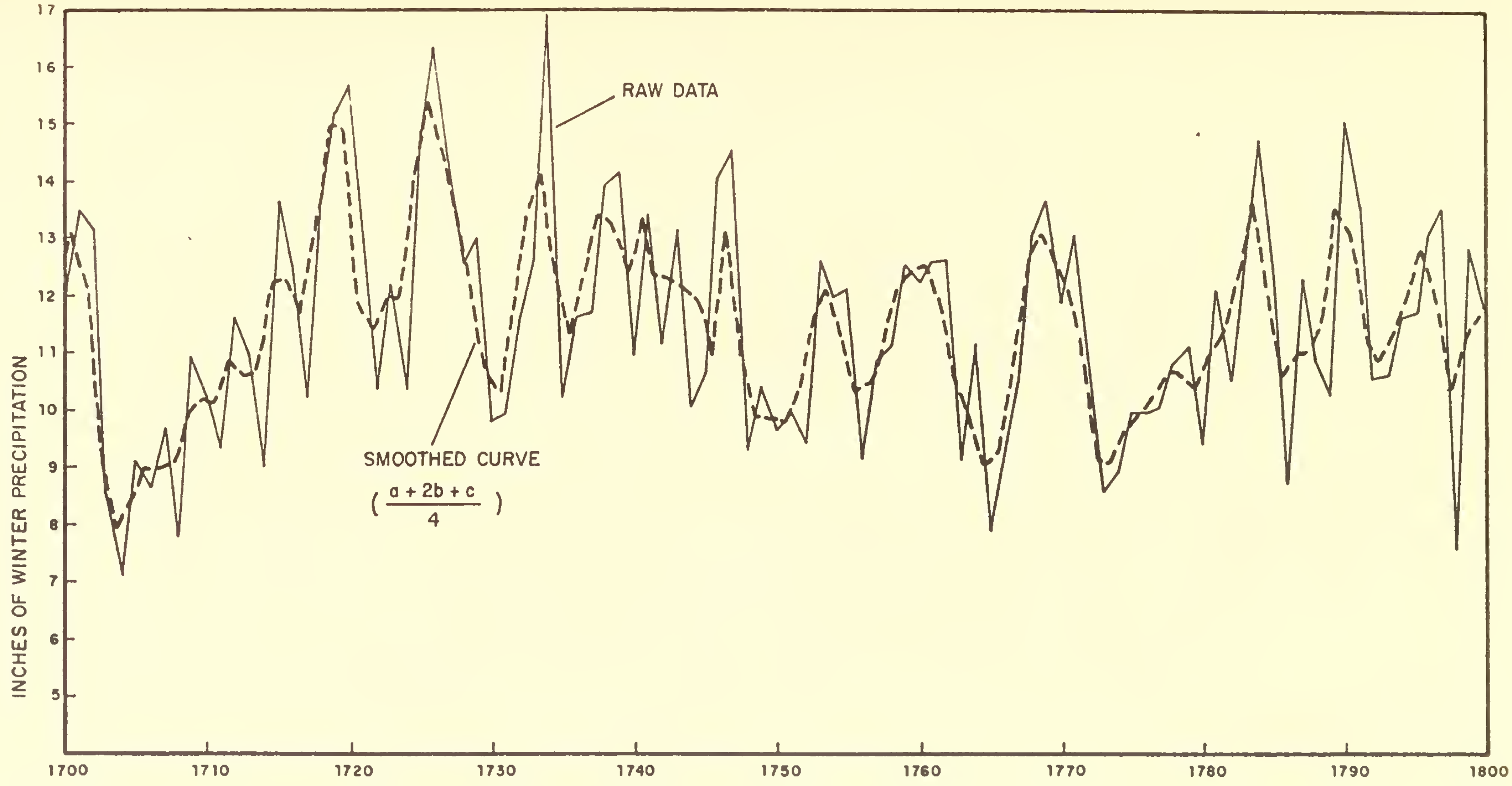

Figure A-7

PREDICTED WINTER PRECIPITATION REGIME USING THE LINEAR REGRESSION MODEL, 1700-1800

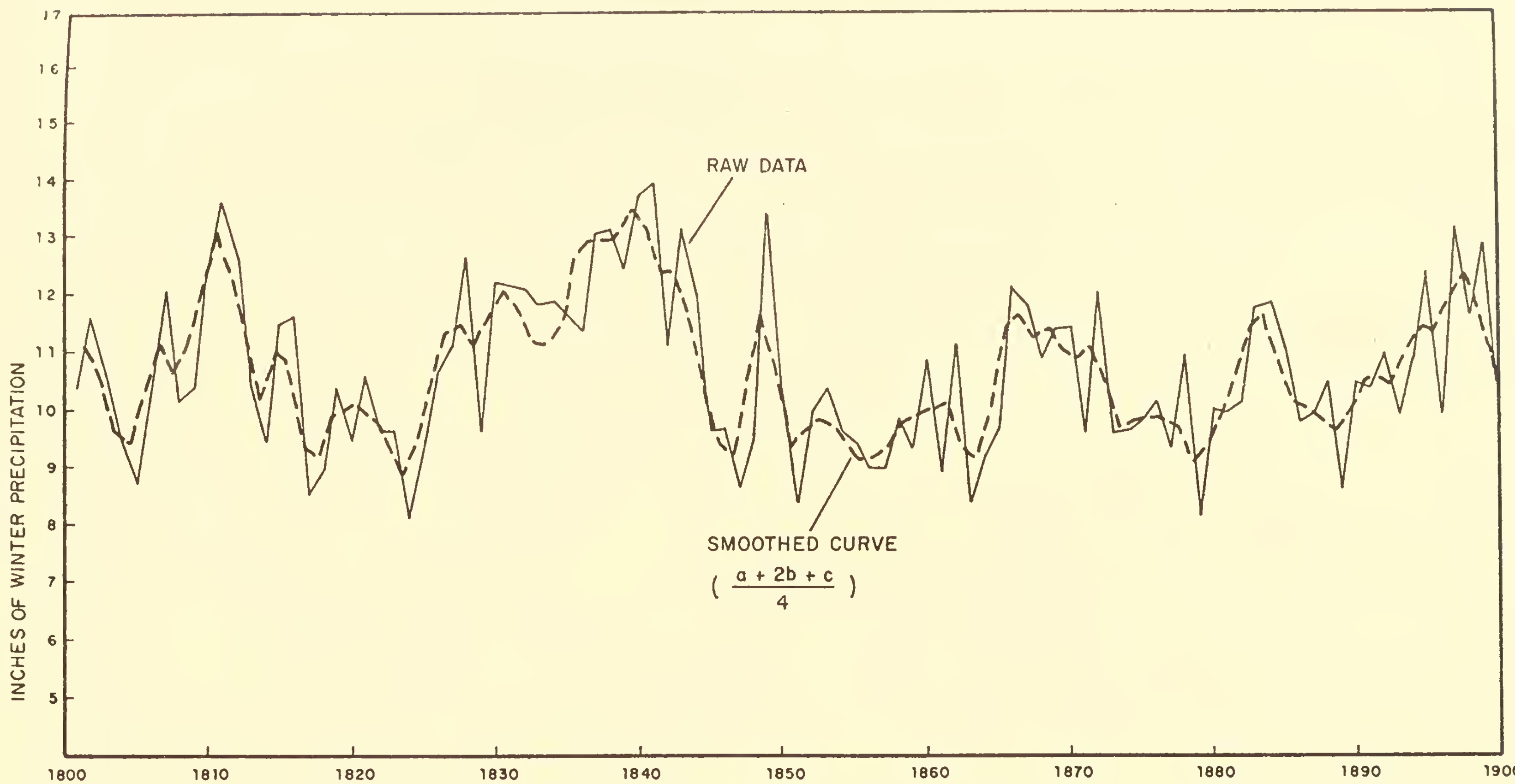

Figure A-8

PREDICTED WINTER PRECIPITATION REGIME USING THE LINEAR REGRESSION MODEL, 1800-1900

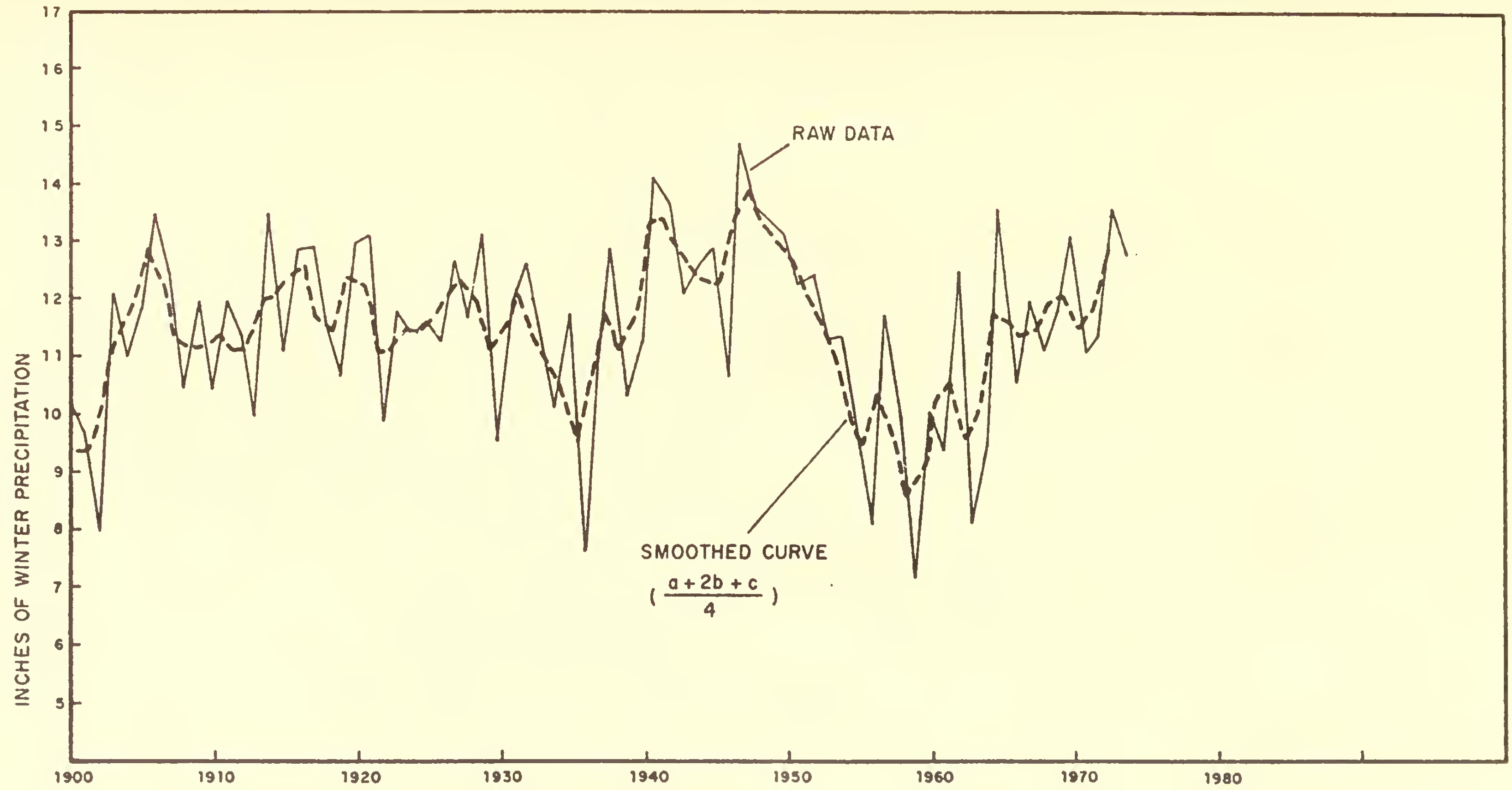

Figure A-9

PREDICTED WINTER PRECIPITATION REGIME USING THE LINEAR REGRESSION MODEL, 1900-1974

An index of tree age versus tree radius was also calculated, using a simple, linear regression (Figure A-10). The data were taken from twelve radii of chained pinyon pine located on Tract C-b. The sections of wood were prepared by sanding with various grades of sandpaper and each ten-year increment of growth was measured to 0.5 millimeters.

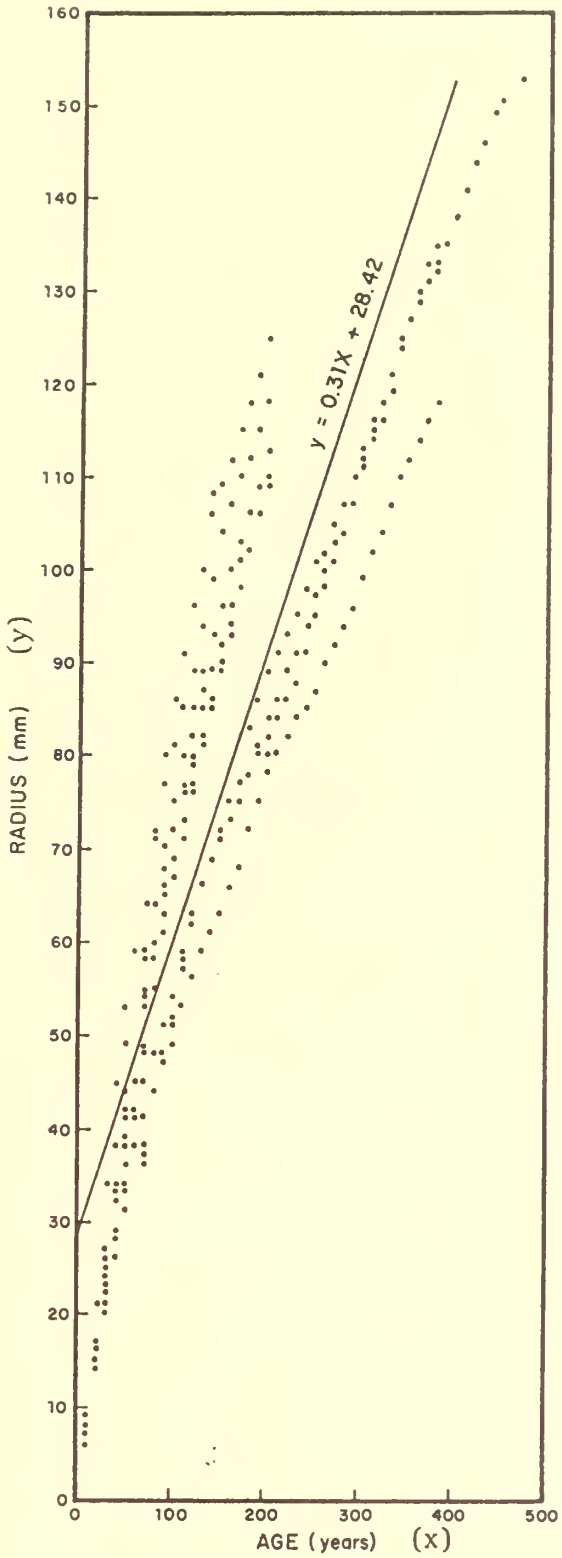

Figure A-10

SCATTER DIAGRAM AND LINEAR REGRESSION
OF TREE AGE AND TREE RADIUS

A.3 Results and Discussion

A.3.1 Master Chronology for the Tract C-b Area

A master chronology was constructed for the Tract C-b area (Figure A-2). It dates the growth increments produced from 1437 A.D. through 1974 A.D. The master chronology can be used to date any section of pinyon pine produced in the area. The primary purpose is to date the annual increments of growth used in the dendroclimatological analysis, however, some general climatological inferences can be made from the master chronology. Each diagnostic growth layer in the chronology represents a striking departure from the mean growth of the trees. The frequency of diagnostic growth layers determined on 100 year intervals from 1437 A.D. to 1974 A.D. is 17.5 percent. This implies that the probability of an extreme departure from the mean for any ten year period is 0.0175 or approximately 2 percent. This frequency roughly describes all the time periods except the 1600's, which have a probability of an extreme departure from the mean of 10 percent (a 1 percent departure for any ten year period). The lower frequency of diagnostic growth layers in the 1600's indicates a more uniformly changing climate with less dramatic fluctuations in climatic factors as compared to the other time periods.

A.3.2 Chaining Practices in the Tract C-b Area

Portions of the Tract C-b have been chained or cabled as part of the Bureau of Land Management's program to improve and maintain what are thought to be natural grasslands. The Forest Service believes that by the beginning of the Twentieth Century pinyon pine and juniper were beginning to invade the natural grasslands. Also Barney and Frischknecht (1974) state that pinyon pine and juniper have expanded their ranges in the Intermountain region primarily in the last 100 years. Results from other studies (West et al. 1975) indicate that 21 percent of sampled pinyon trees, which were not located on rocky hillsides, were less than 100 years old and pinyon trees sampled on the more restricted, rocky sites attained ages in excess of 100 years with a maximum age of 1,000 years.

On the Tract C-b area, which is probably representative of the Piceance Basin, trees sampled were located in a variety of habitat types. Distribution and age structure stands do not give evidence for increased reproduction of, or invasion by, pinyon pine in the area. The ages of the trees sampled in this study range from 132 years to 537 years at the extremes with 64 percent of the trees older than 200 years. Six sections of pinyon pine collected from the chained areas contained only one individual less than 200 years old and the oldest was 470 years old. The master chronology was used to date these sections. Thus, contrary to the studies mentioned above, the data obtained on Tract C-b do not support the assumption that pinyon pine and juniper are or have been invading the Tract.

A.3.3 Growth Rate of Trees in the Tract C-b Area

A linear regression model of tree age radius was constructed for the pinyon pine (Figure A-10). The model is described by the equation $y_{est} = 0.13x + 28.42$ or $x = 3.23\ y_{est} - 91.68$, where y represents the tree radius (mm) and x represents the tree age. The coefficient of determination (r^2) for this model is 0.71. This model can be used as a reference for estimating tree age in the field.

A.3.4 Correlation of Ring-Widths and Winter Precipitation in the Tract C-b Area

The 29 trees used in building the master chronology were correlated with the winter precipitation regimes for Meeker and Rifle, Colorado, using Spearman's rank correlation coefficient. All but three trees correlated to the 5 percent level of significance and 20 trees were used in the dendroclimatic analysis because their high degree of correlation indicates a higher degree of ring-width variability. The overall correlation of the sample trees with the October-to-June precipitation record demonstrates that winter precipitation is a limiting factor in tree growth on sites with high surface runoff. These 20 individuals were used in the multiple regression analysis.

A.3.5 Fluctuations of Climate in the Tract C-b Area

The climatic interpretation of Figures A-4 to A-9 involves the identification of the true climatic cycles and their relative changes, one with another. The cycles have an average period of eleven years or a multiple thereof. The eleven year cycle is often bi-model with an average model period of six years.

From 1437 to 1974 there is no long-term trend of generally increasing or generally decreasing winter precipitation or climatic change. The basic cyclic period of eleven years or multiples thereof are continous throughout the record. Douglas (1936) also shows evidence for the same periodicity of climatic change.

Table A-1

HIERARCHIAL CLASSIFICATION OF HABITAT TYPES FOR TRACT C-b AND VICINITY

Table A-1 HIERARCHIAL CLASSIFICATION OF HABITAT TYPES FOR TRACT C-b AND VICINITY

*AQUATIC AND RIPARIAN AREAS (21.20)

- Open Water (21.215)
- Riparian Vegetation (20.203)
- Cottonwood Grove (20.201)

AGRICULTURAL AREAS (19)

- *Agricultural Meadows (19.191)

DISTURBED AREAS (18)

- Annual Weed Communities (18)

SHRUBLANDS (5)

- Sagebrush (4.041)
  - *Bottomland Sagebrush (4.041)
    - lateral draws
  - *Upland Sagebrush (4.041)
- *Mixed Mountain Shrub (5)
- *Chained Pinyon-Juniper Rangeland (23)
- Greasewood (14.141)
- Rabbitbrush (4.045)

GRASSLANDS (2)

- *Bunchgrass Communities (2.022)
  - South-facing slopes at the lower elevations

ROCK CLIFFS AND TALUS (8.084)

- *Rimrock (8.084)

CONIFEROUS FORESTS (6)

- *Pinyon-Juniper Woodland (9)
  - Burned areas (2.022)
- Douglas-fir Forest (6.061)

ASPEN WOODLANDS (10.101)

*Major habitat types occuring in the Tract C-b study area.

Numbers in parentheses represent the most nearly equivalent habitat of the Bureau of Land Management System (USDI 1975).

Table A-2

MAMMALS IDENTIFIED ALONG THE SPUR CORRIDOR: FROM TRACT C-b TO THE PICEANCE CREEK/PARACHUTE CREEK DIVIDE (7000 TO 8500 FT.)[1]

Table A-2 MAMMALS IDENTIFIED ALONG THE SPUR CORRIDOR: FROM TRACT C-b TO THE PICEANCE CREEK/PARACHUTE CREEK DIVIDE (7000 TO 8500 FT.)[1]

Scientific name, common name*	Habitat type(s) and elevation(s) of identified specimens	Apparent level of abundance**
Insectivora		
1. Sorex vagrans, wandering shrew	Aspen (8400 ft.)	Low
Lagomorpha		
2. Lepus townsendii, white-tailed jackrabbit	Mixed mt. shrub (8200-8500 ft.)	Low
3. Sylvilagus audubonii, desert cottontail	Chained rangeland; Upland sage; mixed mt. shrub (7000-8500 ft.)	Mod.
Rodentia		
4. Clethrionomys gapperi, Gapper's red-backed vole	Aspen (8300 ft.)	Mod.
5. Erethizon dorsatum, porcupine	Mixed mt. shrub (8500 ft.)	Low
6. Eutamias minimus, least chipmunk	Chained rangeland; pinyon-juniper woodland; upland sage; mixed mt. shrub (7000-8500 ft.)	High
7. Lagurus curtatus, sagebrush vole	Upland sage (7400 ft.)	Mod.
8. Microtus longicaudus, long-tailed vole	Aspen (8300-8400 ft.)	Mod.
9. Peromyscus maniculatus, deer mouse	Chained rangeland; pinyon-juniper woodland; upland sage; mixed mt. shrub (7000-8500 ft.)	High

[1] All entries are of mammals positively identified; additional species undoubtedly occur.

POCKET FIGURE 3-I